# Pacific Missile Range Facility (PMRF)
# Species Verification and Satellite Tagging Test: January 2012

## Post-Test Report

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## *Overview and Objectives*

During January 2012, with funding provided by the Chief of Naval Operations (CNO) N45 Energy and Environmental Readiness Division, the Marine Mammal Monitoring on Navy Ranges ( M3R) program supported a marine mammal species verification and satellite tagging test on the Pacific Missile Range Facility (PMRF) prior to a Submarine Commander Course (SCC). The test was a coordinated effort between M3R, Cascadia Research Collective, Commander, U.S. Pacific Fleet, and NAVFAC Pacific.

The primary objectives of the test were to:

1. Visually verify species present on the PMRF acoustic range.
2. Map species acoustic emissions to visual observations including behavior and group size.
3. Deploy satellite tags on marine mammals to monitor movement before, during, and after Navy training.
4. Photograph animals to create a photo-ID record for the Hawaii Range Complex.
5. Collect biological samples (fecal/biopsy).
6. Test the use of a large vessel as a small boat launch platform.

## *Methods and Materials*

The PMRF acoustic range is instrumented with 199 functional bottom-mounted hydrophones which are divided into 3 sub-ranges, the Shallow Water Training Range (SWTR), the Barking Sands Tactical Underwater Range (BARSTUR), and the Barking Sands Underwater Range Extension (BSURE). The combined range extends from shallow water (SWTR, 100-1000m), to mid-water depths (BARSTUR, ~1,000-2,000m), to very deep ocean (BSURE, ~2,000-4,000m). The layout of the hydrophones is optimized for tracking undersea vehicles equipped with a 35 kHz pinger that emits a known signal at a known repetition rate; consequently, it is well suited for detection of in-band marine mammal vocalizations including those produced by beaked whales.

The M3R system processes input from the hydrophones in real time. On-shore acousticians observe and characterize species vocalizations using the M3R utility “MMammal”. This utility allows the user to monitor range activity and to view, on demand, hard-limited, binary spectrograms for hydrophones of interest. The displays have proven reliable at both the Atlantic Undersea Test and Evaluation Center (AUTEC) and the Southern California Offshore Range (SCORE) (Jarvis *et al*. in review). When within detection range of the hydrophone array, animal vocalizations are detected, classified, and localized using the methods described in Morrissey *et al*. 2006. In addition, digital acoustic data from the bottom-mounted hydrophones are recorded for archival, analysis, and/or playback purposes. Recording was only prohibited during times of classified operations on PMRF as directed by the in-water systems manager.

The use of the PMRF acoustic range by M3R and at-sea operations are on a “not to interfere” basis; therefore, during unallocated range time, M3R personnel vectored tagging and observation teams to specific areas and/or marine mammal positions that were derived from acoustic detections. During this test, the efficacy of using a larger vessel, the USNS Sioux as a launch platform for the 24’ observing and tagging Rigid Hull Inflatable Boat (RHIB) was also evaluated. It was hoped this capability would allow the RHIB to reach deeper water, especially during the early morning hours that generally provide lower sea-state conditions. The Sioux was used as an additional observation platform for visual and acoustic observers. Visual observers onboard the Sioux gained considerable height above the water, which increased the area monitored compared to the RHIB. Sonobuoys were launched from the ship and their transmissions monitored onboard by the acoustic observers. While operations were off-range, the sonobuoys provided the sole means of acoustic detection of vocalizing animals.

## *Results and Discussion*

### *Passive Acoustic Monitoring*

Table 1 documents marine mammal species that were acoustically observed on the PMRF hydrophone display. Those species initially identified by M3R acoustically and subsequently visually verified and tagged at-sea under the direction of M3R are indicated in bold. Based on data from the 2011 species verification and tagging test, M3R acoustic observers were able to differentiate and identify both rough-tooth dolphin (*Steno bredanensis*) and common bottlenose dolphin (*Tursiops truncatus*) by visual examination of spectra and time domain waveforms.

| Date | Species | Visually Verified by |
|---|---|---|
| **1/11/2012** | **Spinner Dolphin** | **Cascadia** |
| 1/13/2012 | Spinner Dolphin | Sioux |
| **1/14/2012** | **Pilot whale** | **Cascadia** |
| 1/14/2012 | Rough-toothed Dolphin | Both |
| 1/15/2012 | Sperm Whale | Sioux |
| **1/19/2012** | **Bottlenose Dolphin** | **Cascadia** |
| **1/19/2012** | **Blainville’s Beaked Whale** | **Both** |

*Table 1*- At-sea observations of marine mammal species. Bold entries indicate those obtained under M3R direction

Figure 1 captures a 30 second frame of a *T. truncatus* acoustically identified by M3R and visually verified by Cascadia. Vocalization characteristics are similar to those documented during the 2011 test (Moretti, *et al*., 2011).

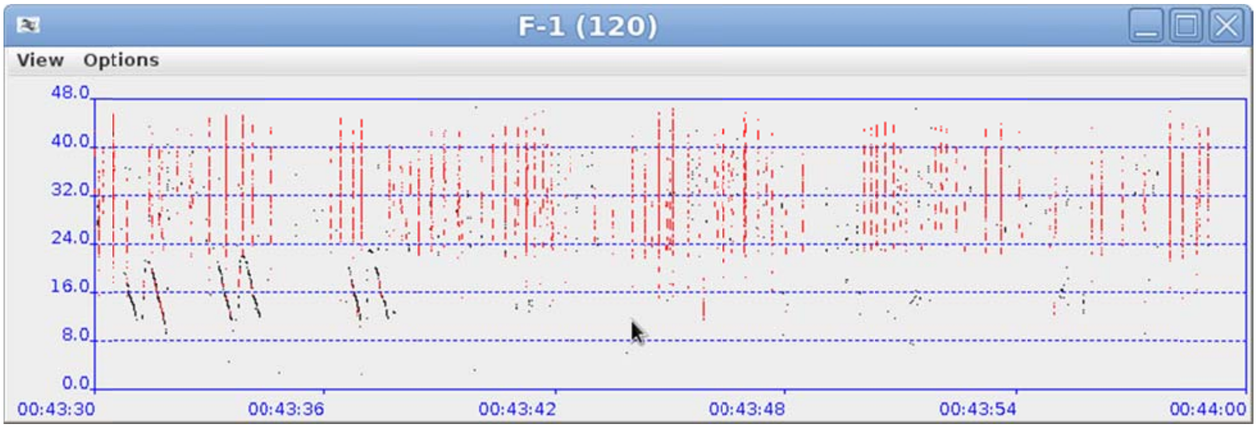


*Figure 1*-MMammal hard-limited binary spectrogram with *Tursiops truncatus* vocalizations

Blainville's Beaked Whale (*Mesoplodon densirostris)* were acoustically detected by M3R and visually verified by at-sea observers at PMRF for the first time. This confirms that the vocalizations observed in 2011 actually were *M. densirostris* (Figure 2). They were acoustically observed over approximately 30 minute time periods which is consistent with known vocal periods for this species during deep foraging dives. The clicks exhibit an Inter-Click Interval (ICI) of approximately 0.3 seconds and dominant energy above 25 kHz (McCarthy *et al.*, 2011). Only sparse, localizations of beaked whales were automatically generated.

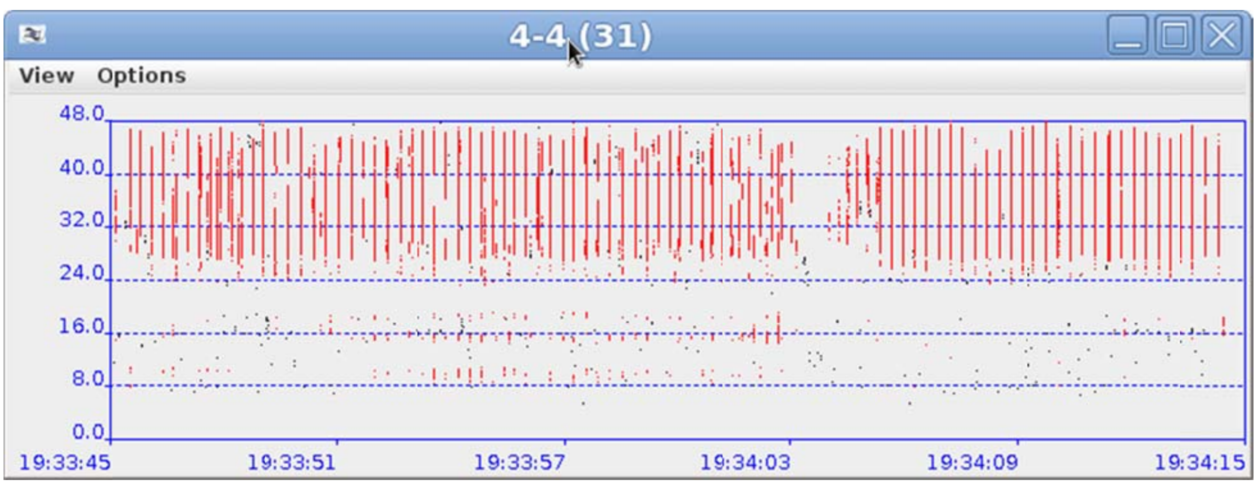


*Figure 2- M. densirostris* echolocation clicks during a deep foraging dive

Sperm whale (*Physeter macrocephalus*), spinner dolphin (*Stenella longirostris),* and short finned pilot whale (*Globicephala macrorhynchus)* vocalizations were detected acoustically and visual observers confirmed the species. As shown in Figure 3, the *P. macrocephalus* produce a repetitive echolocation clicks during deep foraging dives with energy concentrated below 10 kHz.

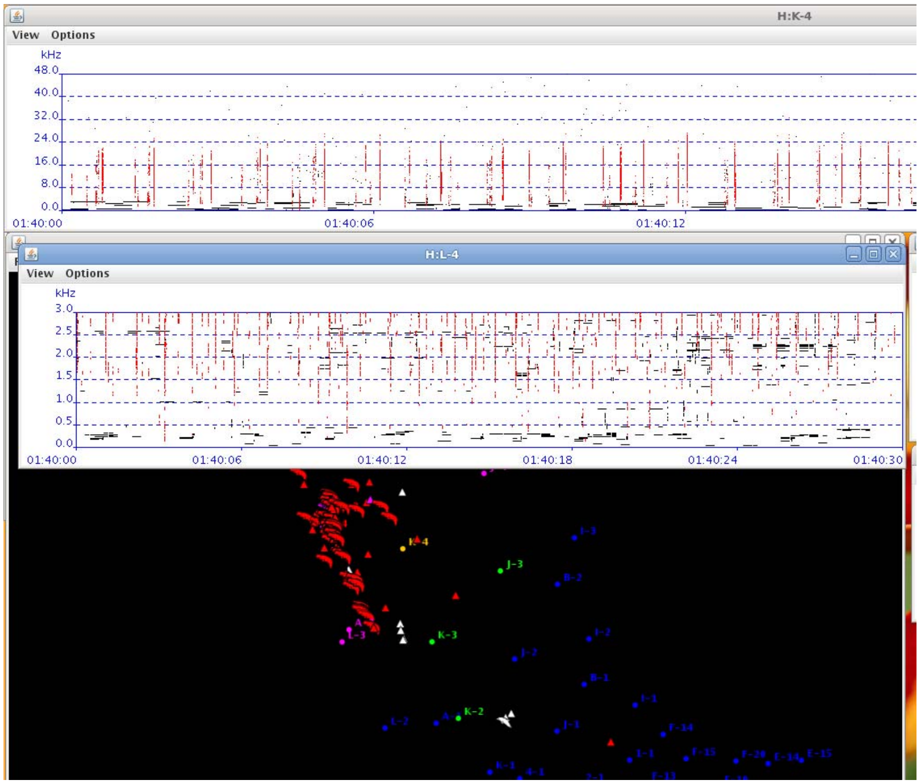


*Figure 3*- The upper and middle show binary spectrogram plots of Sperm whale echolocation clicks. The lower image indicates the whale localization in red with the hydrophones in blue.

Spinner dolphins (*Stenella longirostris*) whistles and repetitive high energy bursts over 10 seconds in duration were observed (Figure 4, burst enlarged in Figure 5). The burst consists of approximately 160 msec amplitude modulated 10.4 kHz tonal signal with a modulation rate of approximately 125 Hz.

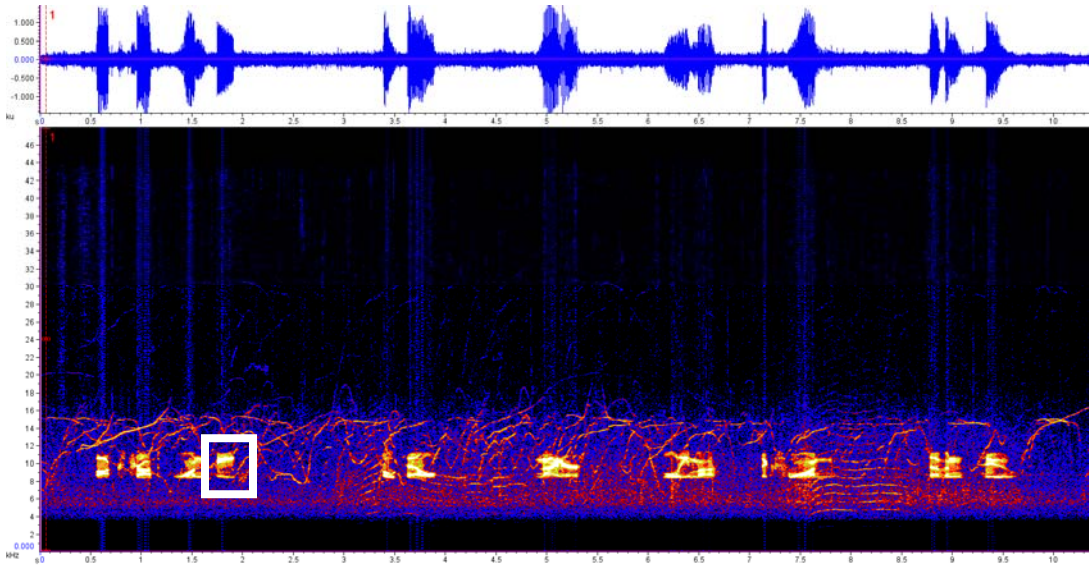

*Figure 4*- Spinner Dolphin sound emissions in the time domain (upper) and frequency domain (lower) with a high energy burst highlighted (white box)

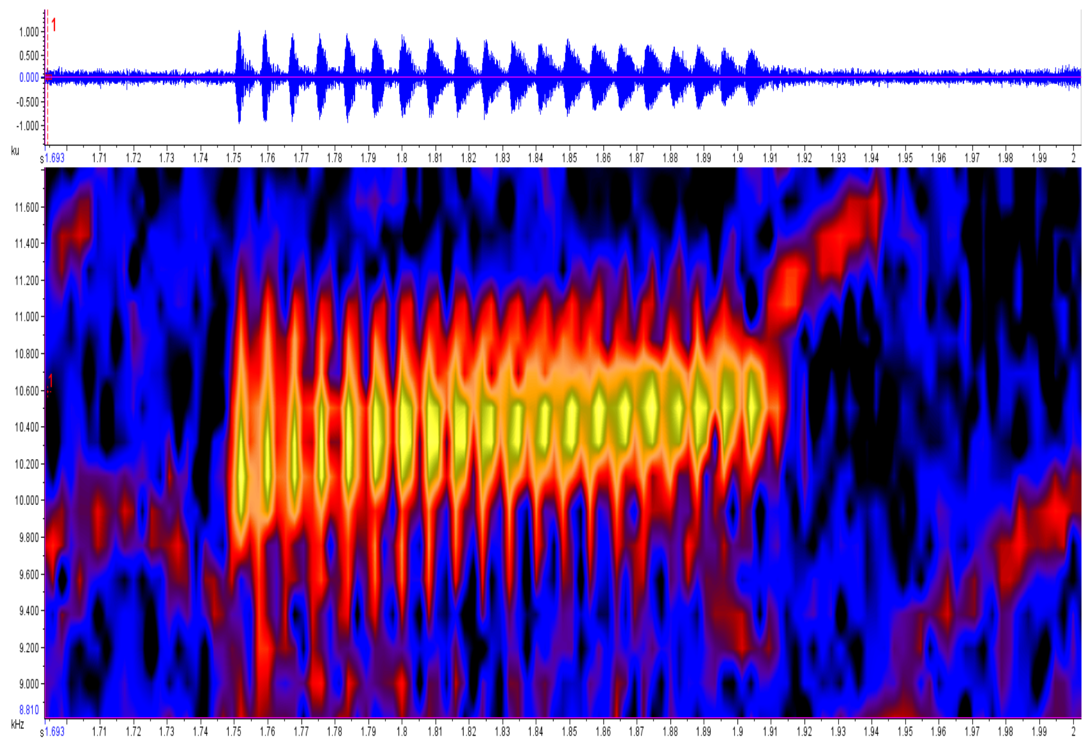

*Figure 5*- Spinner Dolphin 300 msec "Burst" in the time domain plot (upper) and frequency domain (lower)

On many occasions, marine mammal vocalizations were observed that could not be classified to a specific species, but were assigned to broad categories, such as “delphinid” for HF clicks with concurrent whistles (Figure 6).

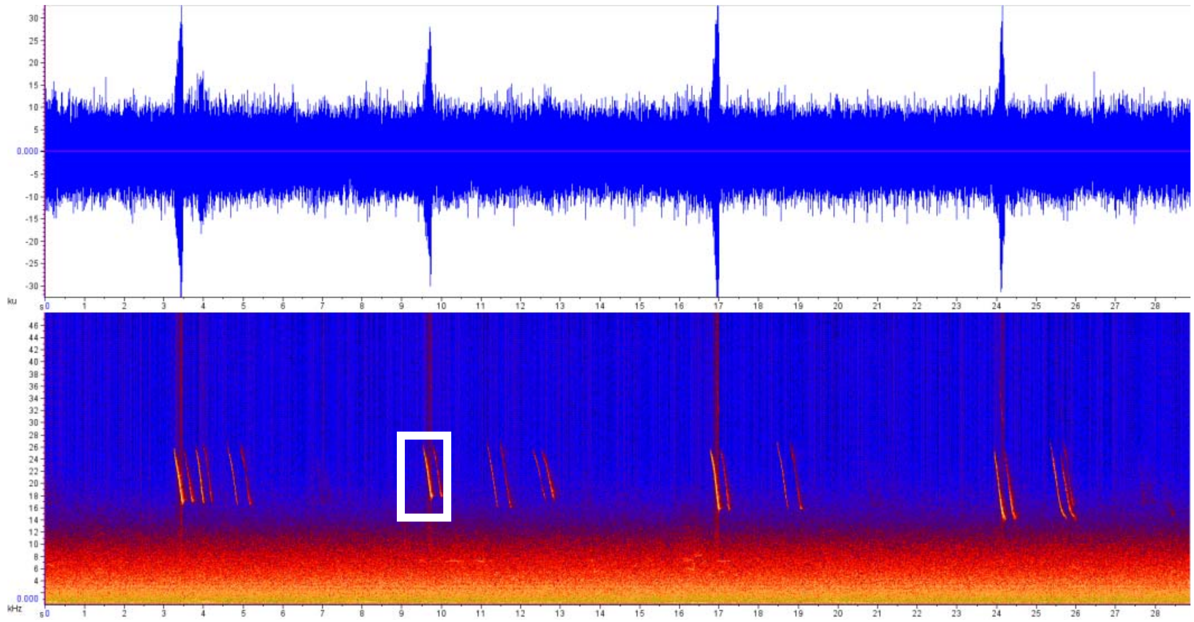

*Figure 6*-Unknown species 30 seconds recording in the time domain plot (upper) and frequency domain (lower). The whistle indicated by the white box is shown in detail as Figure 7.

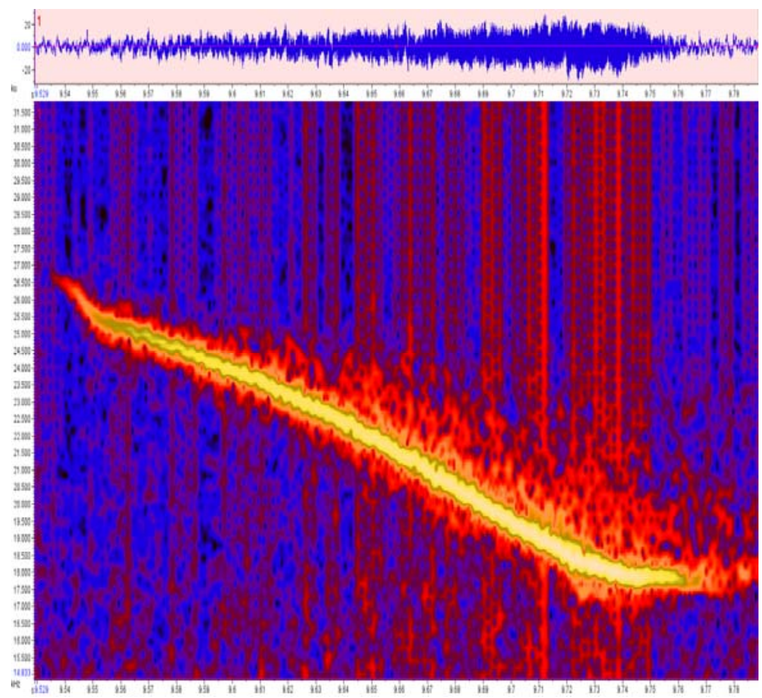

*Figure 7*- Unknown species whistle in the time domain plot (upper) and frequency domain (lower)

***Blainville's Beaked Whale (Mesoplodon densirostris) distribution analysis***

The archived *M. densirostris* detection data for a noncontinuous 201 hour time period recorded between 10-20 January 2012 was grouped following the methods of McCarthy et al. (2011) to determine the duration and center hydrophone associated with each groups' foraging dive.

Prior to grouping, all click trains less than 1 minute or greater than 1 hour in duration were removed. The CTP output was then processed through specialized MATLAB software to identify: groups of echolocating *M. densirostris*, the hydrophones associated with each group, the group sound duration, and the hydrophone receiving the greatest number of clicks (hereby called the center hydrophone). Figure 8 (right) shows the number of times each hydrophone was designated as a center hydrophone of an echolocating *M. densirostris* group by the MATLAB software. There were a large number of single hydrophone groups identified on edge hydrophones, defined as hydrophones along the parameter of the PMRF acoustic range. The click trains associated with these groups tend to be of the same duration as non-edge hydrophones, but have a lower click count. This result is intuitive as detecting clicks on only a single edge hydrophone likely indicates that the echolocating group is outside of the PMRF range and only just within the detection range of the edge hydrophone. These single hydrophone groups provide an indication of *M. densirostris* presence/absence but do not provide enough information to localize the group and direct the visual observers to a position. The left side of Figure 8 depicts *M. densirostris* groups detected on more than one hydrophone; which are more likely to provide localizations for directing visual observers.

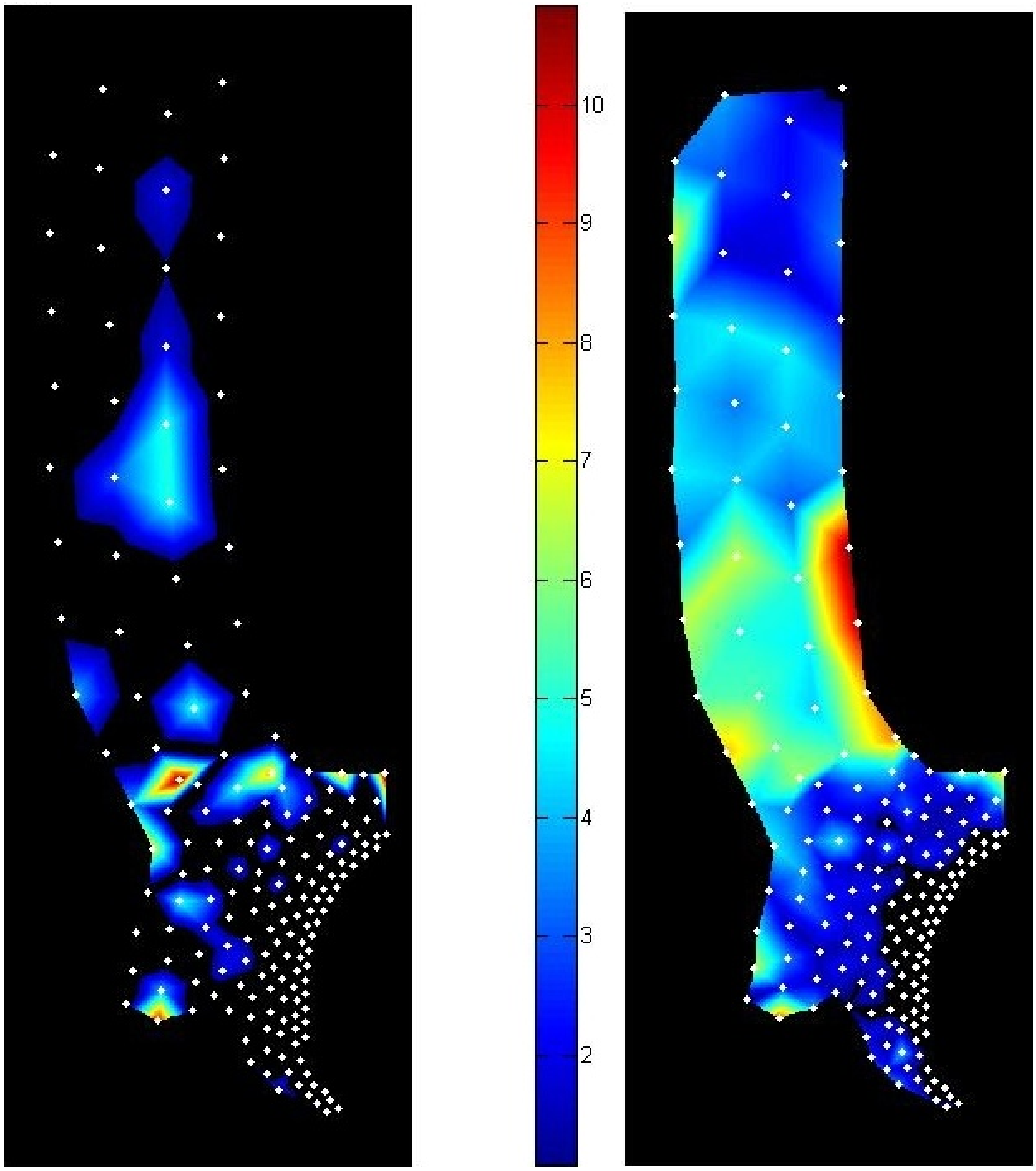


*Figure 8*- Distribution of *M. densirostris* group vocal period per center hydrophone for only vocals group detected on more than one hydrophone (left) and for all size hydrophone groups (right). Color bar indicates number of times that each hydrophone was at the center of an echolocation *M. densirostris* group. White dots indicate hydrophone locations. This data set represents a noncontinuous 201 hour time period between 10-20 January 2012.

## *Ship Operations*

Use of the Sioux as a deep-water launch platform proved problematic. In large swells, issues arose as the RHIB was lifted by the crane, resulting in damage to the RHIB. However, the ship did serve as a valuable observation platform and was able to operate off-shore in marginal sea-state conditions. Several acoustic detections, including *M. densirostris*, were confirmed by visual observations made from the Sioux.

## *Future analysis*

Based on early analysis of M3R acoustic data, the maximum *M. densirostris* density appears to on the northern edge of BARSTUR. If the goal is to tag *M. densirostris* ahead of MFA operations, positioning a RHIB in this area should maximize the number of opportunities. However, experience has shown that the sea-state conditions required for finding and tagging *M. densirostris* are rare in this area, especially after noontime when trade winds increase. Using a larger sea-going vessel as a launch platform could potentially increase the probability of positioning a RHIB offshore at first-light. However, given the experience with the Sioux, the requirements and methods for such a deployment must be reviewed.

A second M3R system dedicated to classified data processing will allow collection of M3R archives on all range hydrophones through mid-frequency active (MFA) operations. These data will provide a more complete record of cetacean distribution and vocal patterns. With species of beaked whales that produce distinct echolocation clicks almost exclusively during deep foraging dives, these vocalizations can be used to map the spatial and temporal distribution of animals before, during, and after naval operations. In addition, these echolocation clicks serve as a proxy for foraging, allowing for investigation of foraging patterns.

The M3R systems can provide near continuous data. As the acoustic emissions of more species are visually verified by at-sea observers, the acoustic classification will improve providing the ability to assess species present, their distribution, and potentially their density. The algorithms to complete such estimates for *M. densirostris* currently exist. They have been validated at AUTEC and are being applied at PMRF as data become available. This capability is also dependent on developing the ability to differentiate among beaked whale species, an effort which benefits from the use of visual observers at sea.

Currently, data collected in 2011 and 2012 are being analyzed to describe the spatial and temporal distribution of *M. densirostris*. These data will be used to estimate *M. densirostris* density and abundance with methods developed by the Density Estimation of Cetaceans on Acoustic Fixed sensors program (DECAF) (Moretti et al. 2010 and Marques et al., 2009.)

Development of passive acoustic density estimation algorithms for additional species is highly dependent on collecting visual observations and acoustic data from tags for each specific species. A PCAD model, to measure the health of the *M. densirostris* population, is also currently under development with data from AUTEC. With the verification of *M. densirostris* at PMRF and the persistent detection of *M. densirostris* foraging dives, the model may be adapted to PMRF. This requires both acoustic data and ancillary data derived from visual observation including group size and age/sex class.

**References**

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