Pacific Missile Range Facility (PMRF)
Species Verification and Satellite Tagging Test
June and July 2012
Post-Test Report

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Marine Mammal Monitoring on Navy Ranges (M3R) program

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Introduction

A marine mammal species verification and satellite tagging test was carried out as part of the Marine Mammal Monitoring on Navy Ranges (M3R) program in collaboration with the Cascadia Research Collective from 11 June to 02 August 2012 at the Pacific Missile Range Facility (PMRF).

The primary objective of the test was to acoustically detect marine mammals at PMRF and vector observers to vocalizing animals. This allowed the team to:

1) Visually verify at-sea species acoustically detected on the PMRF undersea range
2) Deploy satellite tags on marine mammals prior to the Rim of the Pacific Exercise (RIMPAC) to monitor animals' movement before, during and after navy training.
3) Photograph animals to create a photo-ID record for the Hawaii Range Complex
4) Collect biological samples (fecal/biopsy)
5) Document group composition and behavior

Materials and Methods

PMRF Range

The PMRF acoustic range is instrumented with 199 bottom-mounted hydrophones deployed in offset rows to form hexagonal arrays. The array design is optimized for tracking undersea vehicles equipped with a pinger that emits a signal at a known repetition rate with a source level of ~192 dB re µPa@1m and frequency of ~37 kHz. This arrangement of hydrophones is also well suited for detection of in-band marine mammal vocalizations including those produced by beaked whales.

The range is composed of 3 adjacent smaller ranges: the Shallow Water Training Range (SWTR), the Barking Sands Tactical Underwater Range (BARSTUR) and the Barking Sands Underwater Range Expansion (B-SURE). The entire area spans from shallow water (SWTR, 100-1000m), to mid-water depths (BARSTUR, ~1,000 – 2,000m), to very deep ocean (BSURE, ~2,000-4,000m). All three areas were monitored for animal vocalizations in real-time.

M3R Hardware and Software

Analog data from the bottom mounted hydrophones undergo multiple processes within the M3R system as shown in the system configuration diagram in Figure 1 (Jarvis et al., In Review). A duplicate system was installed on the classified side; presently this system is awaiting network security documentation. Once approved, data will be collected during classified MFA operations as well.

After the data from the hydrophones are processed they are stored as detection reports which then provide the input for the M3R analysis suite. This year, for the first time at PMRF, raw hydrophone data were recorded using the newly installed M3R packet recorder.

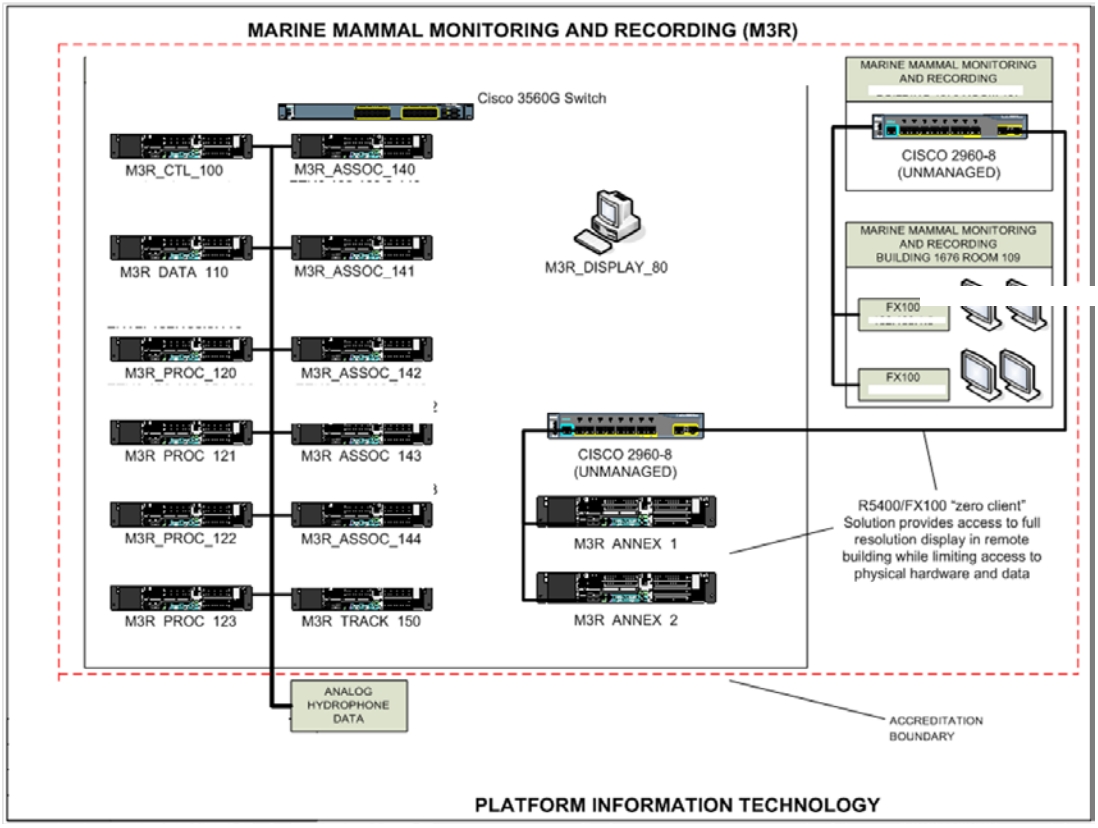

Figure 1-PMRF System Configuration Diagram

Real-Time Monitoring

On-shore acousticians observed and characterized 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 (Jarvis *et al*. in review). Hydrophones are sampled at 96 kHz which provides an analysis bandwidth up to 48 kHz. Detection reports are generated from the output of a simple Fast Fourier Transform (FFT) based detector. An adaptive threshold (exponential average) is run in each bin of the FFT. If there is energy over the adaptive threshold, the bin(s) is set to a "one" and a detection report is generated. These reports are archived and used to form the range monitoring displays.

Animal vocalizations are detected, classified and localized automatically using the methods described in Morrissey *et al*. 2006. However, in the absence of automatically-generated posits, a new M3R tool for manually calculating posits using hand-selected whistles or clicks was used. When the same click or whistle was observed on three or more hydrophones, the tool was used to calculate time delays between hydrophones which were then automatically used to localize the animal's position . Figure 2 displays the same whistle selected on each of three hydrophones and the corresponding calculated position.

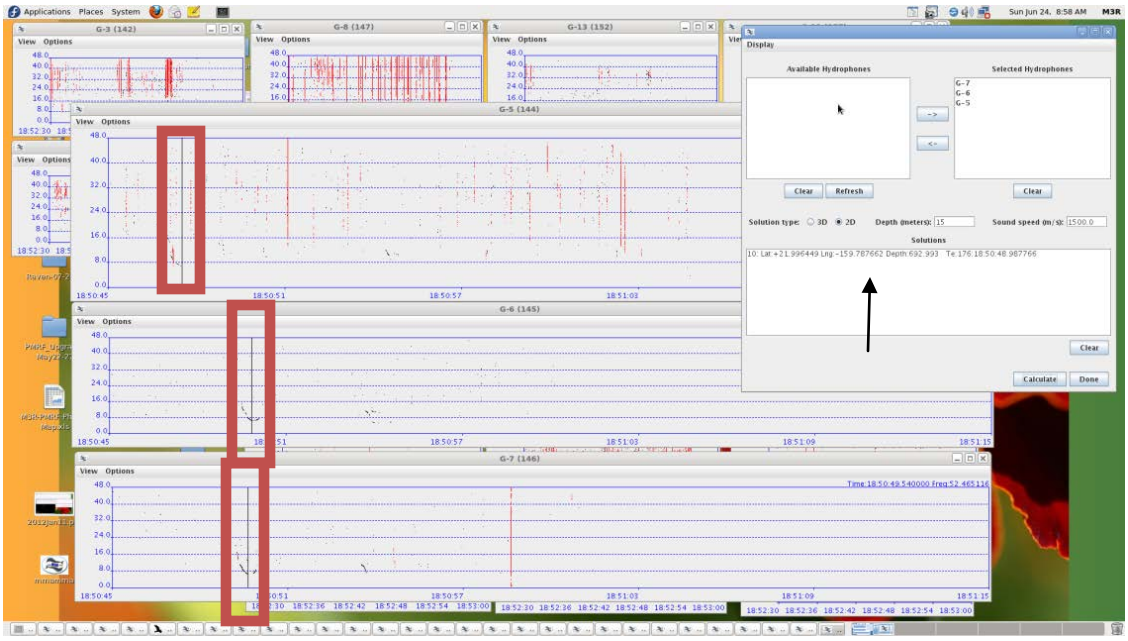

Figure 2- Selection of the same whistle on three different hydrophone (rectangles) to triangulate animal position (arrow point to calculate position)

As described above, the input from the hydrophones undergoes multiple processes which are interpreted by a trained M3R analyst and used to direct at-sea observers to locations of marine mammals on the PMRF acoustic range.

Results

The M3R software suite includes tools that display real time hydrophone data, along with marine mammal classifications and localizations. Hereafter, the term *acoustically observed* refers to marine mammal vocalizations observed by a trained M3R analyst and/or detected using tools from the M3R software suite. *Visually observed* refers to those marine mammal sightings that were made by trained observers at sea. *Confirmed* acoustic observations refer to species' vocalizations that were acoustically observed by an M3R analyst from real-time acoustic data and, as a result of information provided by the M3R analyst to the at-sea observer team, were also visually observed at-sea and associated with a given species . Table 1 provides a summary of the marine mammal species that were acoustically and/ or visually observed by an M3R analyst or by at-sea visual observers, respectively.

	Common Name	Species
Confirmed Observations		
1.	Rough-toothed dolphin	*Steno bredanensis*
2.	Bottlenose dolphin	*Tursiops truncates*
3.	Pilot whale	*Globicephala melas*
4.	False killer whale	*Pseudocra crassidens*
Acoustically Observed Only		
1.	Blainville's Beaked Whale	*Mesoplodon densirostris*
2.	Sperm whale	*Physeter macrocephalus*
Visually Observed Only		
1.	Spinner dolphin	*Stenella longirostris*
2.	Pantropical spotted dolphin	*Stenella attenuata*

Table 1- Summary of species acoustically observed and/or visually observed

During the three week test period, 67 sightings of six species were reported: 34 rough-toothed dolphins, 15 bottlenose dolphins, 10 spinner dolphins, 2 false killer whales, single sightings of pantropical spotted dolphins and pilot whales, and 4 sightings of unidentified dolphins. Also 8 satellite tags were deployed on three species and a location/dive tag was deployed on a rough-tooth dolphin (Baird, 2012).

Confirmed Observations

M3R observers were able to acoustically differentiate among rough-toothed dolphins (*Steno bredanensis,*) bottlenose dolphins (*Tursiops truncatus*), and pilot whales (*Globicephala melas)*, by examining click and whistle structures that were documented during previous PMRF tests (Moretti *et al*., 2011 and Moretti *et al*., 2012).

Rough-Toothed Dolphins (Steno bredanensis)

Cascadia was directed to multiple groups of rough-toothed dolphins during this test with group sizes between 1-10 individuals*. S. bredanensis* whistles were typically single upsweeps or down sweeps with a frequency range between 4-8.5 kHz. The clicks exhibited a highly variable inter-click interval (ICI) and a frequency range from approximately 8-48 kH*z* (Fig. 3 and 4).

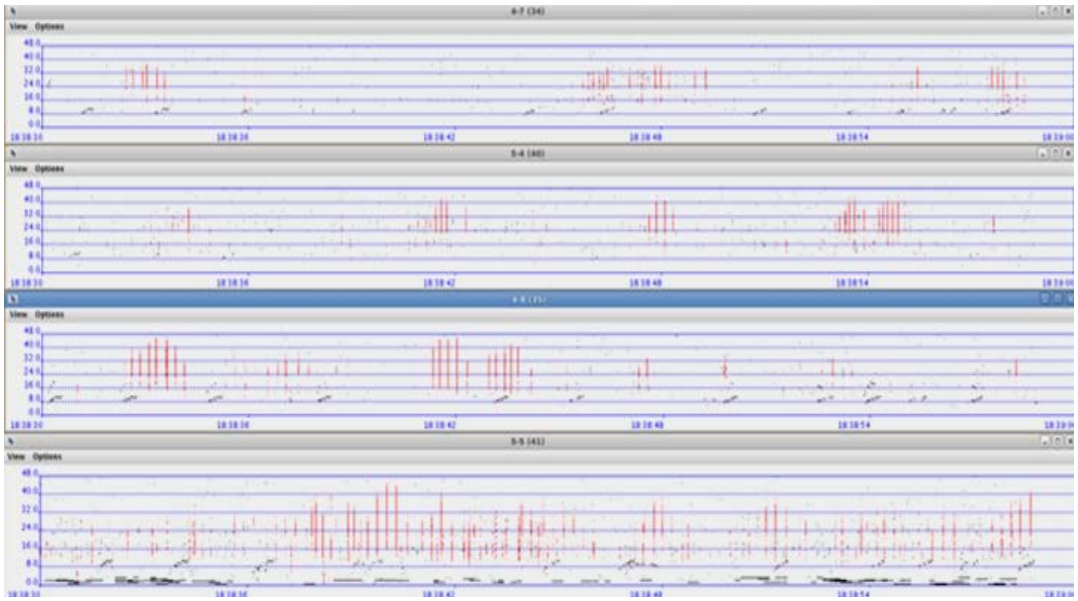

Figure 3-Rough-toothed dolphin after capturing fish

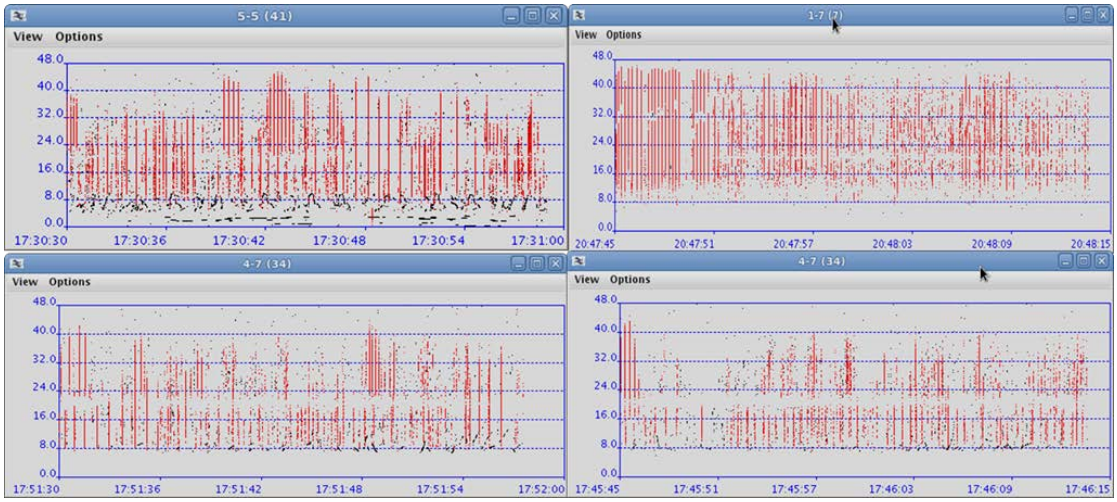

Figure 4-Rough Toothed Dolphin whistles and clicks

Bottlenose dolphins (*Tursiops truncatus*)

The frequency range of *T. truncates* ranged from 8-16 kHz with upsweeps immediately followed by down sweeps forming an inverted "V" (Fig. 5). The clicks exhibited a variable ICI and frequency range. Small groups between 2-9 individuals were visually verified on range.

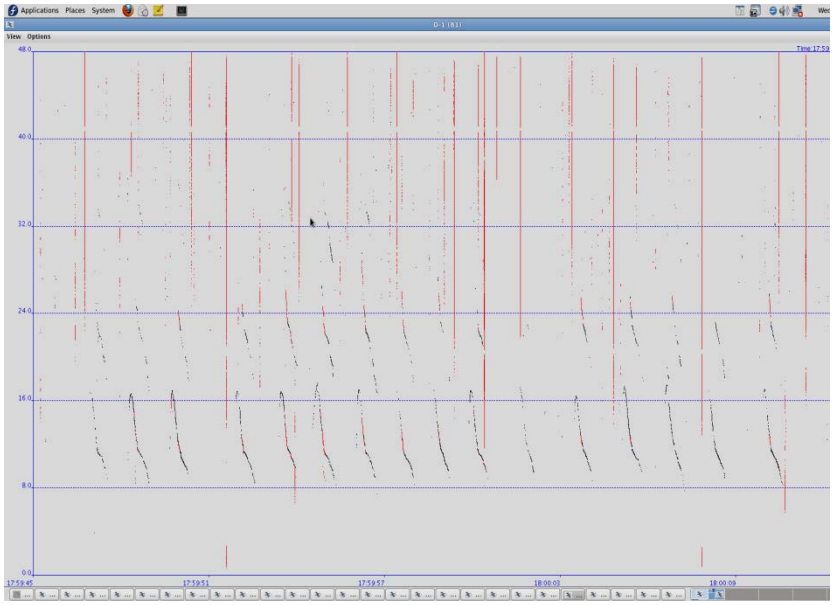

Figure 5-Bottlenose dolphins

Pilot Whale (*Globicephala melas*)

Pilot whales were confirmed on range and their clicks exhibited a variable ICI with a frequency from 8-48 kHz (Figure 6). Their vocalizations were consistent with those previously observed (Moretti *et al*., 2012)

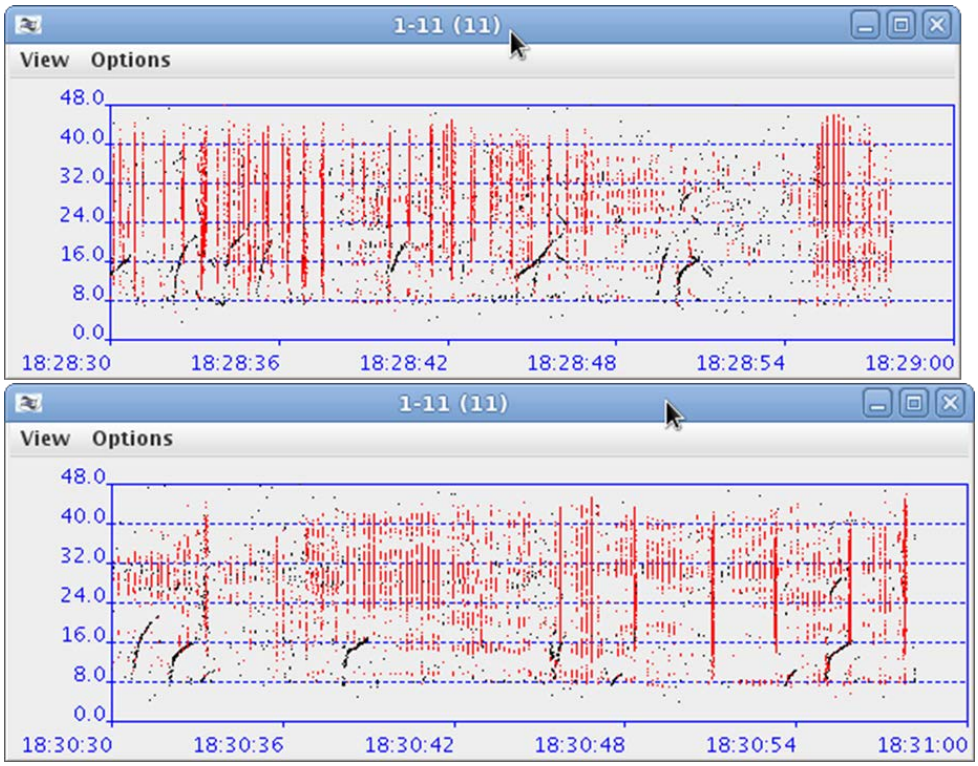

Figure 6-Pilot Whales

False Killer Whale (*Pseudocra crassidens)*

This was the first time that Cascadia encountered false killer whales under the direction of M3R (Figure 7). The click frequency ranged from 8-48 kHz and whistles exhibited upsweeps and down sweeps from 7-9 kHz. After the first visual verification, M3R was able to acoustically identify and to vector Cascadia to other groups for the remainder of the test.

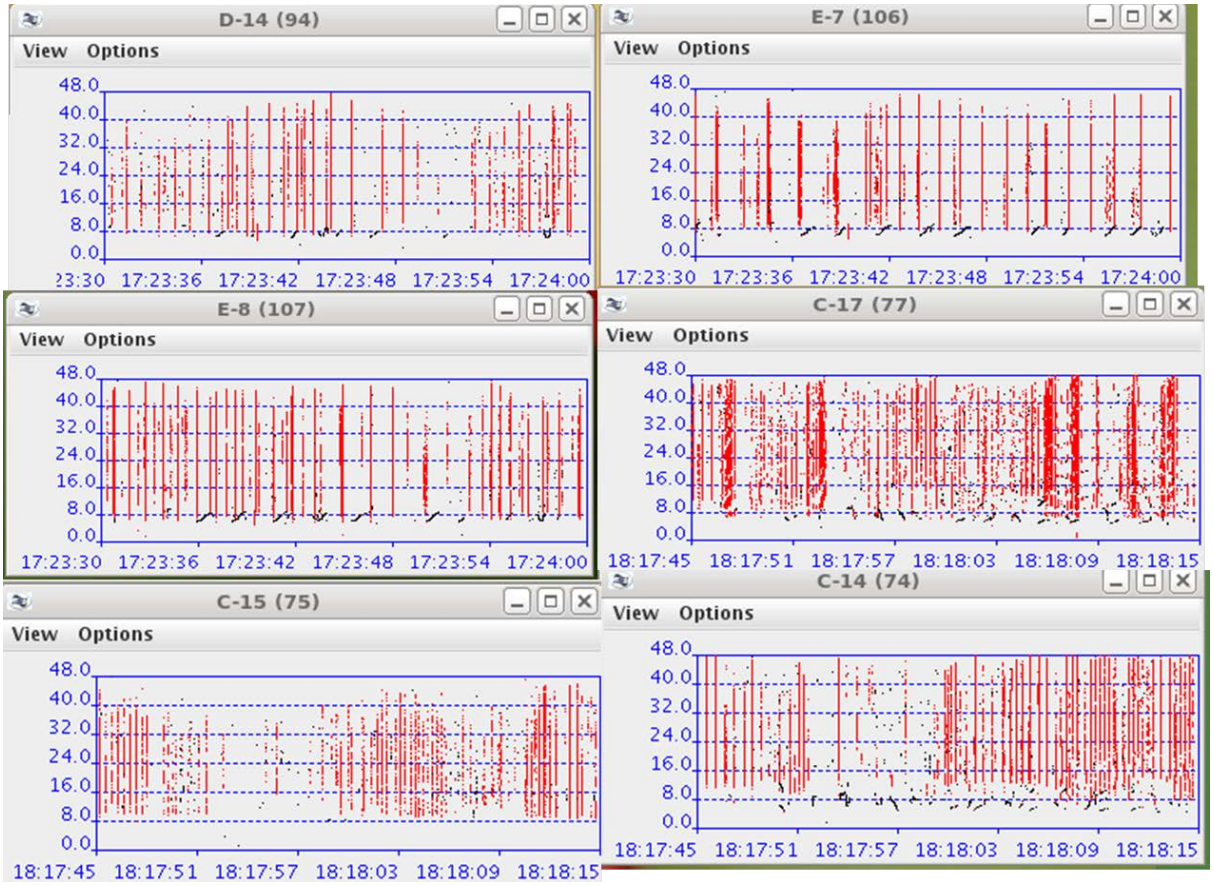

Figure 7-False Killer Whale

Only Acoustically Observed

Blainville's beaked whales (*Mesoplodon densirostris*) and sperm whales (*Physeter macrocephalus)* were not visually confirmed, but the acoustic observations were similar to those confirmed during the January 2012 test (Moretti *et al.,* 2012).

Only Visually Observed

Spinner dolphins (*Stenella longirostris*) were visually observed in groups ranging from 20-30 individuals in shallow water outside the PMRF hydrophone field.

Preliminary Analysis

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

Mesoplodon densirostris echolocation clicks produced within the detection range of the PMRF hydrophone array were automatically detected, classified based on frequency content, and detection reports archived. These archives were evaluated using the M3R Click Train Processor (CTP) software tool to identify click trains recorded from various species. The total number of detections per hydrophone associated with *M. densirostris* clicks trains, determined from the CTP output, is presented in Figure 8. Hydrophones 43-60 (BSURE legacy hydrophones) had very low click train counts and no *M. densirostris* click trains, an expected result of having an 8-20 kHz bandwidth. Hydrophones 159-178, comprising SWTR String G, are no longer active. Additionally, the following hydrophones had between 0-5 groups of any species detected over the entire period, indicating a potential issue withthe hydrophones or within the M3R hardware/software system: 3, 36, 42, 63, 67, 101, 122, and 126. All of these hydrophones were considered "invalid" for the analysis described below.

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 vocal period, and the hydrophone receiving the greatest number of clicks (hereby called the center hydrophone). Figure 9 (left) 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 tended to be of the same duration as non-edge hydrophones, but have a lower click count. Clicks detected on only a single edge hydrophone likely indicate 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 other than to indicate the group is off-range. Figure 9 depicts *M. densirostris* groups detected on more than one hydrophone; these are more likely to provide localizations for directing visual observers.

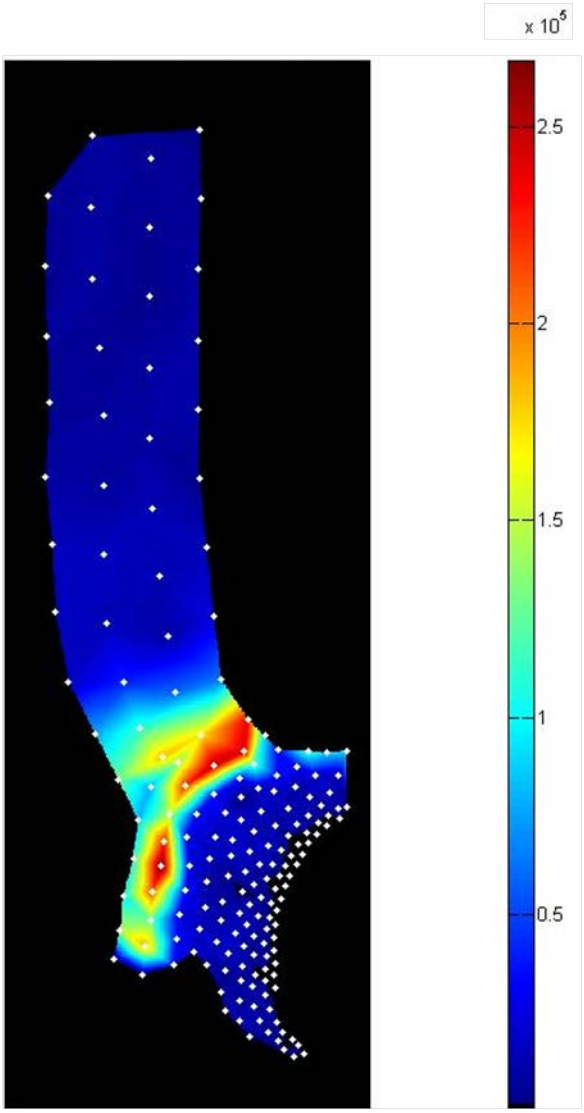

Figure 8. PMRF Click Train Processor Summed Click Counts for the Test Period

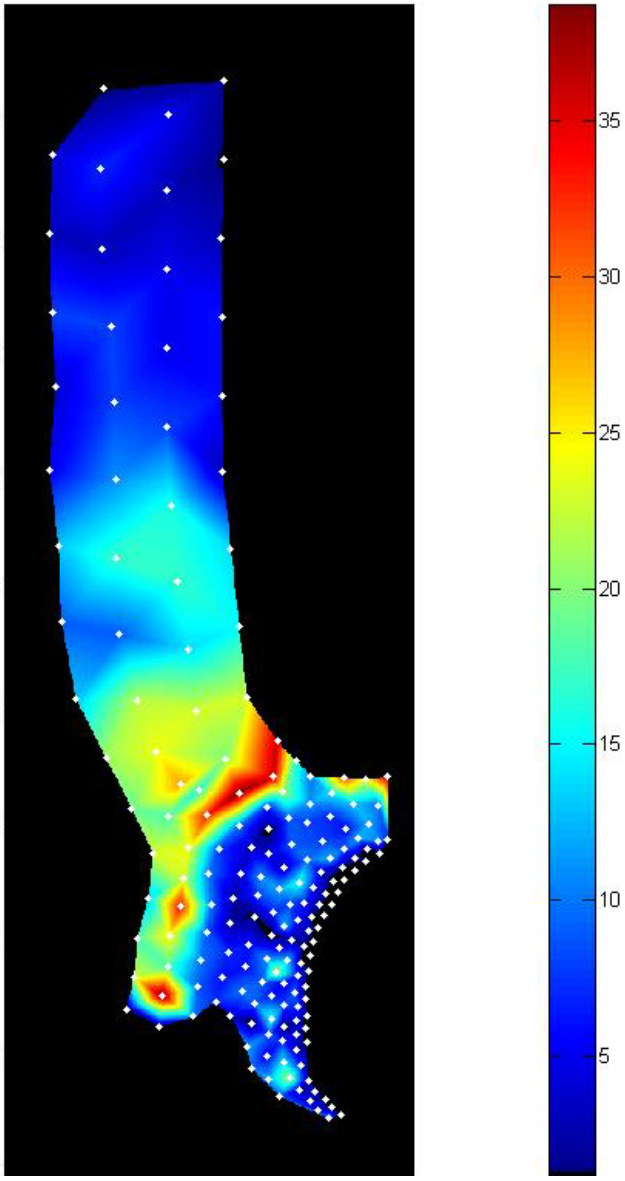

Figure 9. The number of times a hydrophone was at the center of a vocalizing *M. densirostris* group using a linear interpolation in MATLAB for groups detected on at least two hydrophones.

References

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