Marine Mammal Monitoring on Navy Ranges (M3R) Passive Acoustic Monitoring of Abundance on the Pacific Missile Range Facility (PMRF) and Southern California Offshore Range (SCORE)

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14. ABSTRACT
For each of the major Navy ranges, the initial goal is to provide a Marine Mammal Monitoring on Navy Ranges (M3R) system that can be run with minimal operator intervention to collect passive acoustic detection archives on a nearly continuous basis. These archive files provide an electronic record of marine mammal acoustic activity and sonar activity, as well as marine mammal localization data from multiple algorithms with a focus on Blainville's (Mesoplodon densirostris, Md) and Cuvier's (Ziphius cavirostris, Zc) beaked whales. As algorithms become available and are incorporated into the system, algorithm-specific reports can be seamlessly integrated into the archives to provide a time-synchronous history of events.

The M3R systems are being configured at the Southern California Offshore Range (SCORE) and Pacific Missile Range Facility (PMRF) range operation centers to allow range personnel to collect near-continuous detection archives and sampled broadband hydrophone data. When these data are provided with coincident ship track data the Naval Undersea Warfare Center will extract from the archives, in a semi-automated fashion, the following data products, with the mid-term goal of moving to a fully automated process to minimize analyst labor:

1. Beaked whale abundance and density values on a near continuous basis
2. Beaked whale distribution with and without sonar
3. Institution of a software source control within the Navy range signal processor software repository.

Beaked whale abundance will be estimated on a monthly and seasonal basis using the dive start method developed for Md at the Atlantic Undersea Test and Evaluation Center (AUTEC). The method is being adapted for Zc at SCORE and for Md at PMRF. Archive data are being analyzed in a semi-automated fashion to produce the required data products. As presented below, initial abundance results for Zc at SCORE and Md at PMRF were completed.

To estimate abundance and density, the start of a group's deep foraging dive must be detected. These dive starts also can be used as a proxy for the animals' temporal and spatial distribution. Thus, the distribution of beaked whales can be examined along with estimates of abundance/density.

In total, these data can be used to support extended research into the effect of sonar on marine mammals. For example, prior and on-going studies have established that beaked whales are displaced when exposed to mid-frequency active sonar. The research suggests beaked whales increase their time submerged and ascend to the surface away from the source. By combining passive acoustic localization of the animals and precise ship tracks, a risk function for behavioral disruption of Md at AUTEC in terms of foraging dives as a function of Received Level (dB RLrms re μPa) was developed. The same model is being adapted for use with Zc at SCORE and cross-validated with Md data from PMRF. These behavioral results are being used to develop a Population Consequences of Acoustic Disturbance model to estimate the cumulative effect of repeated sonar exposure on a population level, a key question from an environmental management perspective.

In fiscal year 2015, tasks necessary to provide M3R monitoring systems on both the PMRF off the Hawaiian Island of Kauai and the SCORE in the San Nicolas Basin off San Clemente Island were completed. The following tasks were undertaken:

1. Hardware/software upgrade of M3R Linux-based cluster signal processor at SCORE and PMRF, which includes a full range of broadband recording and integrated data archives.

2. Submission of an information assurance accreditation designed to readily accept security patches at intervals as specified in the accreditation.

3. Initial analysis of beaked whale detection archives to establish methods and baseline abundance at PMRF and SCORE.

15. SUBJECT TERMS
monitoring, marine mammal, passive acoustic monitoring, SCORE,Southern California Offshore Range, San Nicolas Basin, San Clemente Island, PMRF, Pacific Missile Range Facility, Hawaii Range Complex, beaked whales

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Acronyms

AUTEC	Atlantic Undersea Test and Evaluation Center
A/D	Analog to Digital
AUV	Autonomous Undersea Vehicle
dB	Decibel
DSP	Digital Signal Processor
FFT	Fast Fourier Transform
GPS	Global Positioning System
I/A	Information Assurance
ICI	Inter-Click Interval
M3R	Marine Mammal Monitoring on Navy Ranges
Md	*Mesoplodon densirostris*, Blainville's beaked whale
Me	*Mesoplodon europaeus,* Gervais' beaked whale
MFAS	Mid-Frequency Active sonar
NUWC	Naval Undersea Warfare Center
ONR	Office of Naval Research
PIT	Platform Information Technology
PCAD	Population Consequences of Acoustic Disturbance
PMRF	Pacific Missile Range Facility
RL_{rms}	Received Level root mean squared
SCORE	Southern California Offshore Range
SOAR	Southern California Anti-submarine warfare Range
SOCAL	Southern California
SVMJ	Jarvis Support Vector Machine classifier
TA	Type Accreditation
USWTR	Undersea Shallow Water Training Range
Zc	*Ziphius cavirostris*, Cuvier's beaked whale

1. System Overview

In FY15, tasks necessary to provide M3R monitoring systems on both the Pacific Missile Range Facility (PMRF) off the Hawaiian Island of Kauai and the Southern California Offshore Range (SCORE) in the San Nicolas Basin off San Clemente Island were completed.

To realize this capability the following tasks were undertaken:

1. Hardware/software upgrade of M3R Linux-based cluster signal processor at SCORE and PMRF which includes a full range of broadband recording and integrated data archives.

2. Submission of an I/A accreditation designed to readily accept security patches at intervals as specified in the accreditation.

3. Initial analysis of beaked whale detection archives to establish methods and baseline abundance at PMRF and SCORE.

2. FY15 Goals

For each of the major Navy ranges, the initial goal is to provide a Marine Mammal Monitoring on Navy Ranges (M3R) system that can be run with minimal operator intervention to collect passive acoustic detection archives on a nearly continuous basis [1, 2]. These archive files provide an electronic record of marine mammal acoustic activity, and sonar activity, as well as marine mammal localization data from multiple algorithms with a focus on Blainville's (*Mesoplodon densirostris*, *Md*) and Cuvier's (*Ziphius cavirostris*, *Zc*) beaked whales. As algorithms become available and are incorporated into the system, algorithm specific reports can be seamlessly integrated into the archives to provide a time-synchronous history of events.

The M3R systems are being configured at the SCORE and PMRF range operation centers (ROC) to allow range personnel to collect near-continuous detection archives and sampled broadband hydrophone data. When these data are provided with coincident ship track data NUWC will extract from the archives, in a semi-automated fashion, the following data products, with the mid-term goal of moving to a fully automated process to minimize analyst labor:

1. Beaked whale abundance and density values on a near continuous basis
2. Beaked whale distribution with and without sonar
3. Institution of a software source control within the Navy range signal processor software repository.

Beaked whale abundance will be estimated on a monthly and seasonal basis using the dive start method developed for *Md* at AUTEC [2]. The method is being adapted for *Zc* at SCORE and for *Md* at PMRF. Archive data are being analyzed in a semi-automated fashion to produce the required data products. As presented below, initial abundance results for *Zc* at SCORE and *Md* at PMRF were completed.

To estimate abundance and density, the start of a group's deep foraging dive must be detected. These dive starts also can be used as a proxy for the animals' temporal and spatial distribution [3]. Thus the distribution of beaked whales can be examined along with estimates of abundance/density.

In total, these data can be used to support extended research into the effect of sonar on marine mammals. For example, prior and on-going studies have established that beaked whales are displaced when exposed to Mid-Frequency Active (MFAS) sonar [3]. The research suggests they increase their time submerged and ascend to the surface away from the source [4, 5]. By combining passive acoustic localization of the animals and precise ship tracks, a risk function for behavioral disruption of *Md* at AUTEC in terms of foraging dives as a function of Received Level (dB RLrms re μPa) was developed [6]. The same model is being adapted for use with Cuvier's beaked whale (*Zc*) at SCORE and cross-validated with *Md* data from PMRF. These behavioral results are being used to develop a Population Consequences of Acoustic Disturbance (PCAD) model to estimate the cumulative effect of repeated sonar exposure on a population level, a key question from an environmental management perspective [7].

3. System Status

To finalize the transition of the current prototype system a set of user utilities and system changes were completed. The systems now provide the basic passive acoustic detection data to support passive acoustic species monitoring by on-site range personnel.

3.1 System Hardware

Current system hardware at SCORE and PMRF is a mix of computer nodes that span multiple technology generations, making maintenance by range personnel impractical. All systems were reconfigured to provide uniform hardware at each site. This reconfiguration was implemented in the most cost effective manner possible by installing new nodes at PMRF and repurposing PMRF nodes at SCORE. Nodes that were obsolete and unsupported were all replaced.

Given its location along with per diem and travel costs, new nodes were used to completely reconfigure the PMRF system even though the current PMRF M3R system had the latest hardware. The hardware from PMRF was distributed and re-purposed at both SCORE and AUTEC. Outdated single-core computer nodes at both SCORE and AUTEC were replaced with the high-performance dual quad-core nodes shipped from PMRF. Uniform hardware and spares were provided to each of the ranges making maintenance by range personnel possible.

The current PMRF hard disks were replaced with flash drives containing the latest software build. The flash drives provide a dramatic improvement in system stability. The M3R installations at all three ranges suffer from significant power issues with numerous power outages. This is especially true at PMRF. Repeated abrupt hard shutdowns can damage traditional hard drives leading to node reboot failure. The solid-state flash drive provides a stable configuration that is largely immune to hard shutdowns. In addition, mandated information assurance (I/A) patches are required on a regular basis. To meet I/A requirements, the system is configured as a closed enclave with no external network connection. Updates are loaded via hard media. This is being accomplished by sending compact flash memory devices pre-loaded with the necessary updated system software along with the latest security to be installed by range personnel. A consolidated system build controlled by a master build script allows integration of software updates and patches as required.

3.2 Information Assurance (I/A) Approval

Operation of all computer based hardware within Navy facilities requires Information Assurance (I/A) approval. The architecture of all major Range Digital Signal Processors (DSPs) evolved from the M3R signal processor architecture. Currently, a Type Accreditation (TA) is nearing approval for the Range DSP under which the M3R DSP is included. The TA defines the approved DSP hardware architecture, software, and maintenance schedule including the frequency of patches and upgrades. The system is defined as a closed enclave that does not directly interface with external networks. Therefore, patches will be supplied via flash drives as discussed in section 8.1.

The M3R system includes display computers that fall outside the standard Range TA. A separate TA was completed based on the prior AUTEC PIT and Range DSP TA. The TA is an extension of the Range DSP TA. As of 1 February, 2016 the M3R TA has been drafted, submitted, and is under review.

The PMRF hydrophone data were received from the range signal processer data collection node via a gigabit Ethernet cable. This configuration presents issues in regards to the proposed TA. To mitigate this complication, Analog to Digital (A/D) boards were procured for the M3R signal processor. A separate data collection node was installed to digitize the analog signals from all 188 active hydrophones. This required the installation of additional patch panels to allow the use of high density cables to simplify system wiring and preclude the use of individual BNC cables.

The SCORE system receives signals for the new hydrophones via an Ethernet cable. Like PMRF, to meet I/A requirements, this link must also be replaced via the installation of an A/D board. The installation is tentatively scheduled for the spring of 2016.

4. Long Term Abundance and Density

The M3R program has detected via passive acoustics and visually verified via expert observers Blainville's beaked whales *Md* at AUTEC and PMRF and *Zc* at AUTEC and SCORE [8, 9]. In addition, Gervais' beaked whale (*Mesoplodon europaeus, Me*) has been documented at AUTEC. Beaked whales associate and dive together in groups. They execute deep foraging dives at measurable rates and echolocate only during these dives [10, 11]. Therefore, the detection of beaked whale echolocation clicks indicates a group of animals in a deep foraging dive. If the mean group size and foraging dive rate is known, animal abundance and density can be readily estimated [12, 13].

The M3R capability initially provided allows long-term monitoring of beaked whales on all three major ranges using the dive counting method developed for *Md* at AUTEC. Tracking trends in abundance over months, seasons, and years is possible as data become available. Interestingly, initial *Zc* abundance estimates at SCORE over nearly a continuous year of data suggested a reduction in the number of animals during summer months, reaching a low in August. This monthly analysis presented below was expanded to all datasets and shows the same seasonal pattern. In another study based on limited data, Moore *et al.* have suggested that the population of beaked whales is in decline in Southern California [14]. These findings highlight the need for long-term, continuous monitoring. Again, M3R datasets are examined here in an initial effort to examine population trends across multiple years.

Over time, M3R passive acoustic data from the Navy Ranges will be able to provide a more robust long-term beaked whale abundance estimate for the Navy Ranges. Such estimates can be cross-validated with those produced using existing photo-ID data via mark-recapture methods [9].

Additionally, the dive counting method requires an estimate of group size and dive rate. *Zc* group size in SOCAL is being derived from visual sighting data from collaborating on-water partners. Dive rate is being measured via depth recording mid-term satellite tags [15, 16, 17].

These methods are not restricted to beaked whales but can be adapted as the in-situ call rate statistics become available for other species, including large baleen species. For example fin whales are routinely detected and localized on SCORE and were recently detected and visually verified at PMRF. North Atlantic right whales are present near the proposed site of the Undersea Shallow Water Training Range (USWTR). If the call rates for these ESA listed species are known, passive acoustic density estimation methods can be developed, keeping in mind rates may vary between sexes, seasons, locations, and environmental conditions. However, for large baleen species validation of passive acoustic methods via visual surveys is straight forward as compared to cryptic beaked whale species.

4.1 PMRF Abundance

Initial abundance values were derived for PMRF. Four years of data archives from 2011 to 2014 were examined. The archives include nine periods ranging from less than a day to just under 20 days. Beginning in February, 2016, system operation is being monitored by Range personnel. This should result in near-continuous data records at PMRF.

The data archives used for this analysis contained detection reports from a Fast Fourier Transform (FFT) based detector [1]. This broad-based energy detector runs a 2048 FFT on every hydrophone on the PMRF range. The detector implements an adaptive threshold in each FFT bin. If any bin is above threshold, a detection report is generated. Simple frequency segmentation is used to identify potential beaked whale clicks. Those detection reports with sufficient bins above threshold and dominant energy above 24 kHz are extracted. Two separate programs were used to mark the presence and duration of GVPs. First detection reports classified as beaked whale were passed through a program (click train processor) to form individual click trains. These click trains are then associated into groups by a second program (auto-grouper). The phone with the largest number of detected clicks was designated as the group center. The total number of clicks detected on all hydrophones within the groups along with the start and stop time of the GVP was recorded.

The FFT detects broadband energy. To reduce the number of false positives, the group data were further screened. Baird et al. report a mean dive duration of 54.6 min (sd=4.) However, the GVP duration (Figure 1), that is, the time over which the animal is vocally active, had a measured mean value 32.92 min (sd=13.01min, n=2,424) (see below) which is in similar to numbers reported from *Md* tags at AUTEC [12]. Therefore, any GVP with a duration greater than 60 minutes (~μ+2sd) was removed.

With an inter-click interval of 0.3 clicks/sec, an animal at depth could produce up to ~6,200 clicks. Therefore, any group with less than a total of 500 click detections (~3 min) was removed. However, since the click energy is focused in a narrow beam, detection of the clicks will depend on the orientation of the animal to the hydrophone [18]. At AUTEC, with hydrophone spacing similar to BARSTUR, comparison to tag data suggests that within a 4 km range, 94.8% of the clicks detected were at an angle of less than 30° relative to the narrow [18], on-axis beam pattern of the animal. Consequently, it is assumed that maximally less than half of all emitted clicks within a 7 hydrophone tracking array will be detected on the surrounding hydrophones. Therefore, any group vocal period with a total click detection count greater than 20,000 was removed. This strongly suggests that overlapping GVPs within an array or adjacent array, or potentially animal groups with large numbers of animals, may be removed resulting in a conservative (low) estimate of abundance.

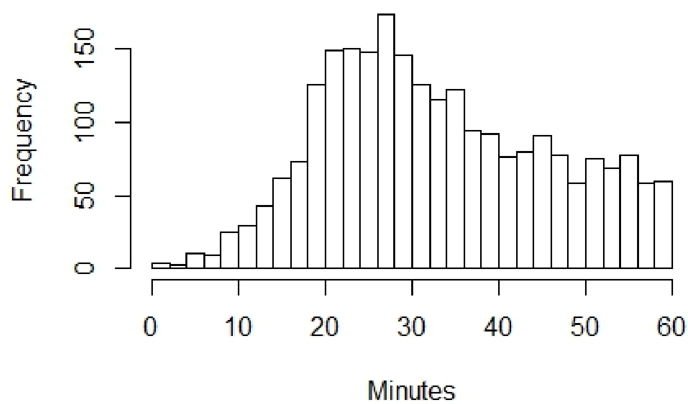

Figure 1: Group Vocal Period Duration in Minutes (μ=32.92min (σ=13.01min, n=2,424)

The dive counting method as given below and presented in Moretti et al., 2010 was applied to estimate the overall abundance.

$$D = \frac{n_d s}{r_d T}$$

n_d = total number of dive starts
s = average group size
r_d = dive rate (dives/unit time)
T = time period over which the measurement was made
A=measurement Area

Where density is given by

$$D = \frac{n_d s}{r_d TA} \qquad \text{A=measurement Area}$$

Equation 1&2 : Dive counting abundance and density estimating equations (Moretti et al., 2010)

To parameterize the equation, the dive rate and group size from Baird et al., 2008 were used.

Table 1: Mean dive rate and group size estimates from Baird et al., 2008

Mean Dive Rate (dive/hr)	**Var**	**Dives/Day**	**Group Size mean**	**Var**
0.46	0.01	11.04	3.69	5.71

An initial abundance estimate for a limited 85 hour period in 2010, previously completed with data extracted manually by an analyst, suggested on the order of a dozen *Md* in three groups on the range at a time.

Table 2. 2010 estimate of Md abundance and number of groups present on PMRF, with groups manually identified over an 85.15 hour period

Animals	Groups
12.34 (6.63-18.055)	3.34 (1.8-4.89)

In FY 15 data from all M3R tests conducted from 2011 to 2015 on the PMRF range were analyzed using the semi-automated methods described above. Nine individual data periods for all available archive data were incorporated (Figure 2).

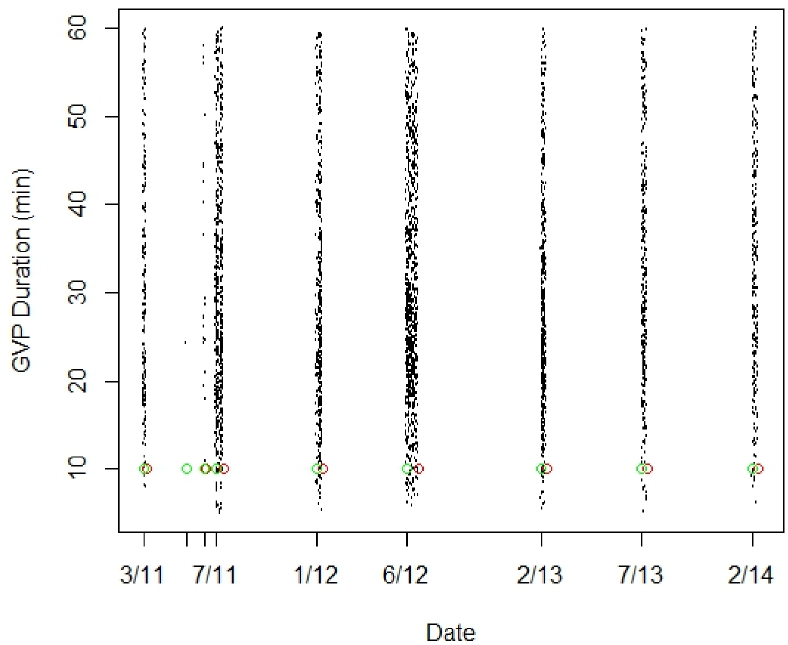

Figure 2. GVP duration (min) vs. start date. The start (green) and stop times are marked by green and red circles respectively

The nine recording periods ranged from .01 to 19.95 days for a total of 78.74 days (Table 1).

Table 3: PMRF Data Summary

Start Date	Total Days	GVPs BARSTUR & BSURE	Abundance BARSTUR & BSURE	+/-CI (95%)	Groups
3/16/11	5.69	55.00	13.23	5.55	3.58
5/28/11	0.01	1.00	28.97	12.15	7.85
6/29/11	2.03	7.00	4.13	1.73	1.12
7/20/11	12.60	115.00	16.26	6.82	4.41
1/9/12	11.10	81.00	12.19	5.12	3.30
6/13/12	19.95	222.00	14.91	6.26	4.04
2/1/13	8.87	59.00	17.86	7.50	4.84
7/25/13	8.81	65.00	11.88	4.98	3.22
2/1/14	9.68	78.00	9.01	3.78	2.44
Total	78.74	683.00	128.43	53.89	34.80
Mean	8.75	75.89	14.27	5.99	3.87
Sd	5.89	65.29	6.85	2.87	1.86

The estimate of abundance for the nine periods extracted semi-automatically from the data are shown in Figure 3. Note the 2010 estimate using groups identified by an analyst are included (12.34) and close to the next estimate obtained in 2011 (13.23). The data suggest a stable but low *Md* population on the PMRF range.

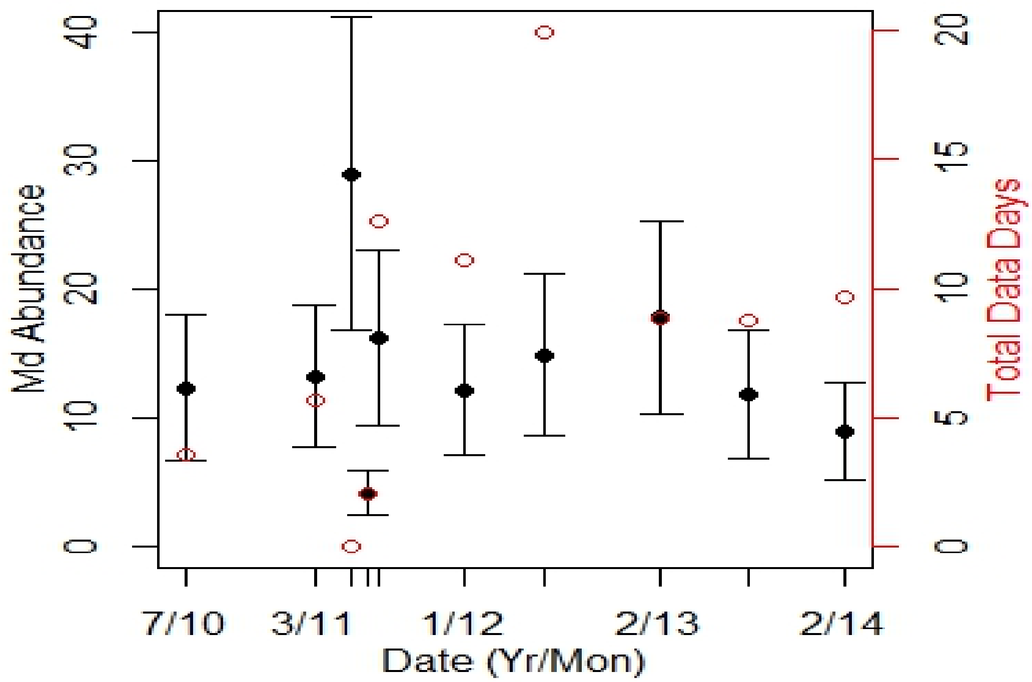

Figure 3: Abundance estimate for all nine data periods from 2011 to 2014 extracted semi-automatically along with the 2010 estimate for analyst identified groups. (95% confidence bars)

4.2 SOAR Abundance

The passive acoustic methods described above were applied to SCORE detection archives from 2010 to 2014. However, the SCORE archives include detection reports from the Jarvis Class-Specific Support Vector Machine classifiers (SVMJ). The SVMJ provides improved discrimination between *Zc* and dolphin echolocation clicks, with a per click correct classification rate of greater than 90%. This is particularly important at SCORE were the abundance of interfering species call is particularly high.

As with *Md* clicks at PMRF, click trains were first compiled for SVMJ *Zc* click detection reports. The click trains were then associated into groups using the auto-grouper software. The start and stop time of uninterrupted data periods within the archives were determined (Figure 4). A new period was marked if no group was detected for a period of 24 hours. It should be noted that the M3R processor is disabled for some operations which leads to such occasional data gaps. The total archive lengths varied from a low of 104.79 days in 2010 to a high of 239.12 days in 2014 (Table 4Table 4).

Table 4. Yearly Data Record Length

Year	Total Record Time (Days)
2014	239.12
2013	158.27
2012	131.5
2011	212.29
2010	104.79
Total	845.97

GVPs were extracted and the duration of each determined (Figure 4). For 2014, 11,386 GVPs were recorded with a mean duration of 40.6 min (sd=16.1 min). For groups at SCORE, a duration of up to 80 minutes was accepted. Overlapping groups have been frequently visually observed at SCORE, which results in GVPs with extended duration. Also, tag data have shown dive times well over an hour in duration with a maximum recorded dive time of 137 min [15]. Reduction of the maximum GVP duration to 60 minutes results in a mean of 36.04 min (sd =12.72 min, n=9857).

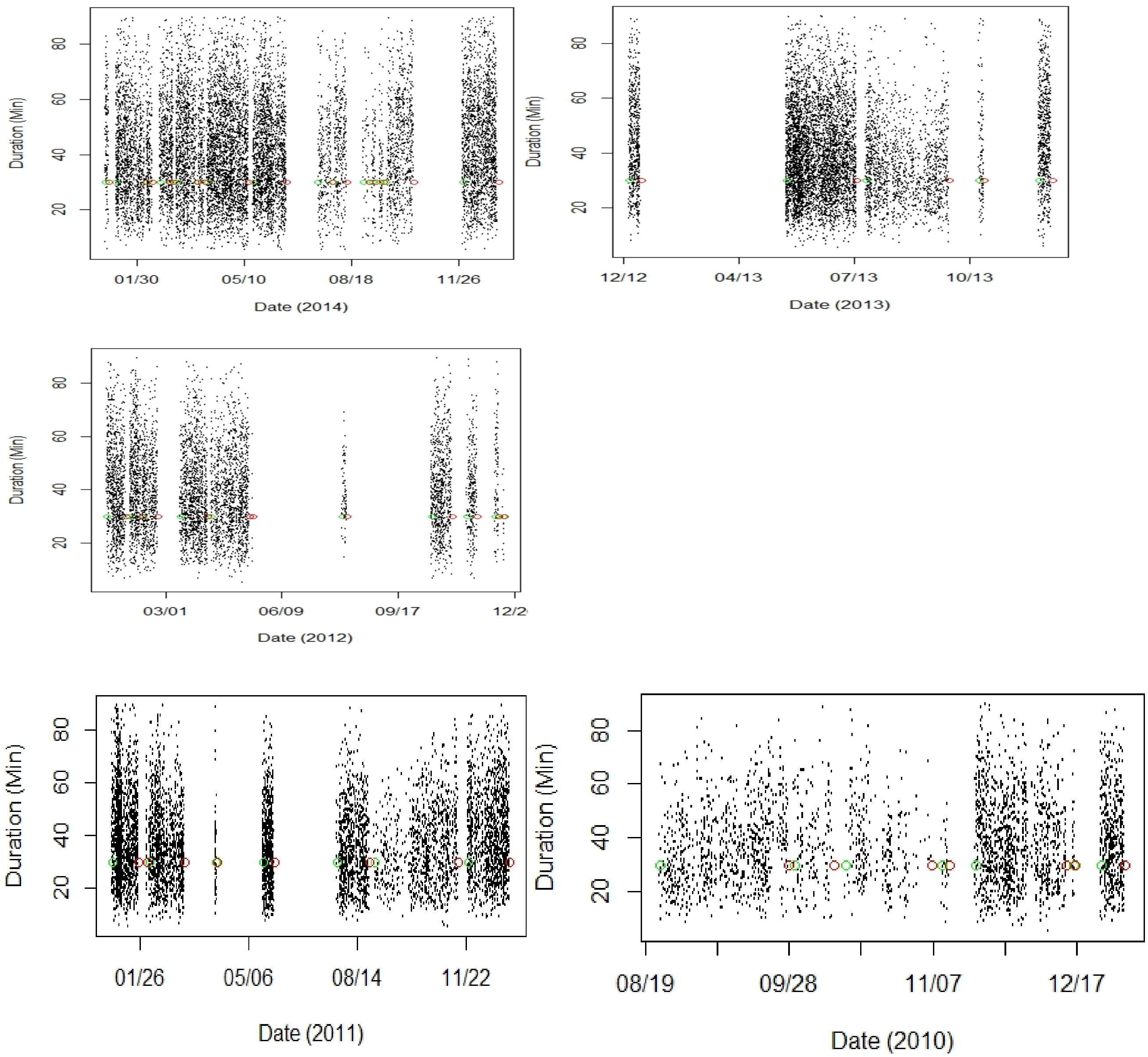

Figure 4. Group Duration vs. time for 2010 – 2014. Each dot represents one Zc GVP. The start (green) and stop (red) of each data period are indicated by the circles.

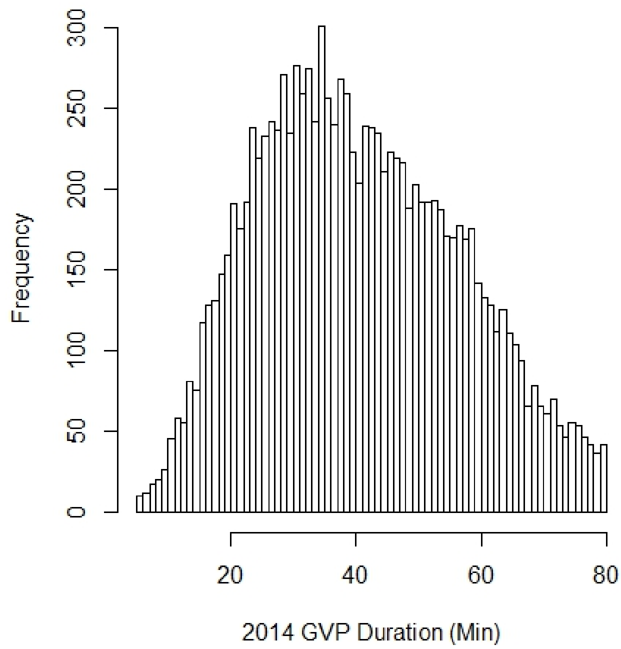

Figure 5. GVP duration (minutes)

An estimate of abundance for each month where data were available was calculated using the dive counting method outlined above [12]. A mean dive rate of 7.2 dives/day (sd=.05, n=1142) as reported by Schorr et al., 2014 was used. Group data were provided (E. Falcone) through the analysis of photo-ID data collected during tests through 2015. A mean group size of 3.22 animals per group (sd=2.06, n=78) was calculated. It should be noted that many of the photo-ID data were collected during tests on the SCORE range. This may bias the estimate higher, since the on-water observers were directed to vocalizing *Zc* groups by M3R passive acoustic monitors with a preference for what were believed to be larger groups. In addition, the group sighting probability most likely goes up for larger groups that are easier to locate, especially under less than ideal sighting conditions.

The results of the monthly abundance analysis for 2010 to 2014 are presented in Figure 6. In each year the data were arranged by month. Groups were extracted and abundance estimated. Figure 8 provides a plot of the density estimate for the month of December, for which data were available in each of the five years 2010 to 2015. Data were also combined across years (Figure 8) to produce a monthly average for 2010 to 2014.

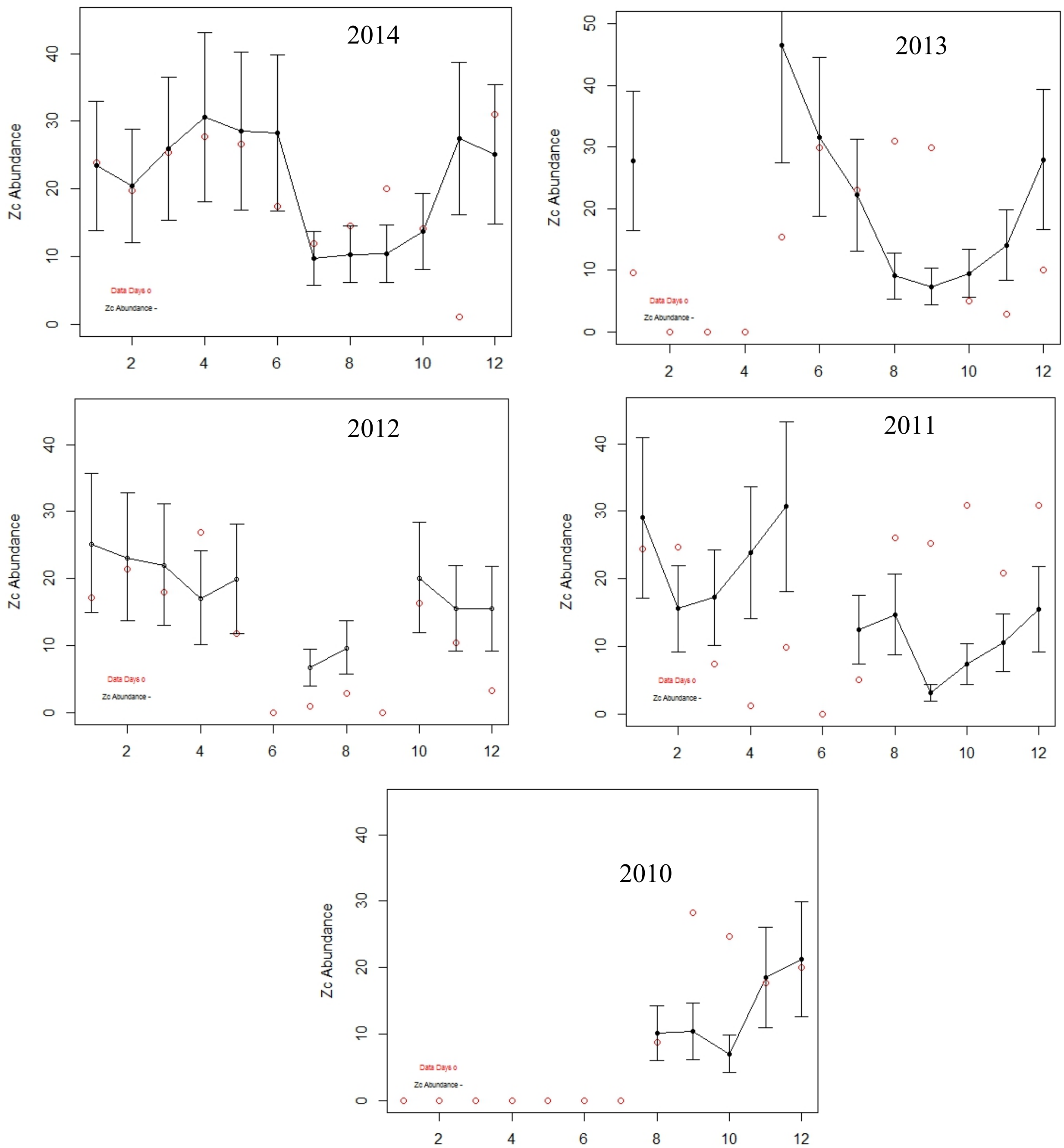

Figure 6. Monthly abundance estimate 2010-2015 for months with data archives.

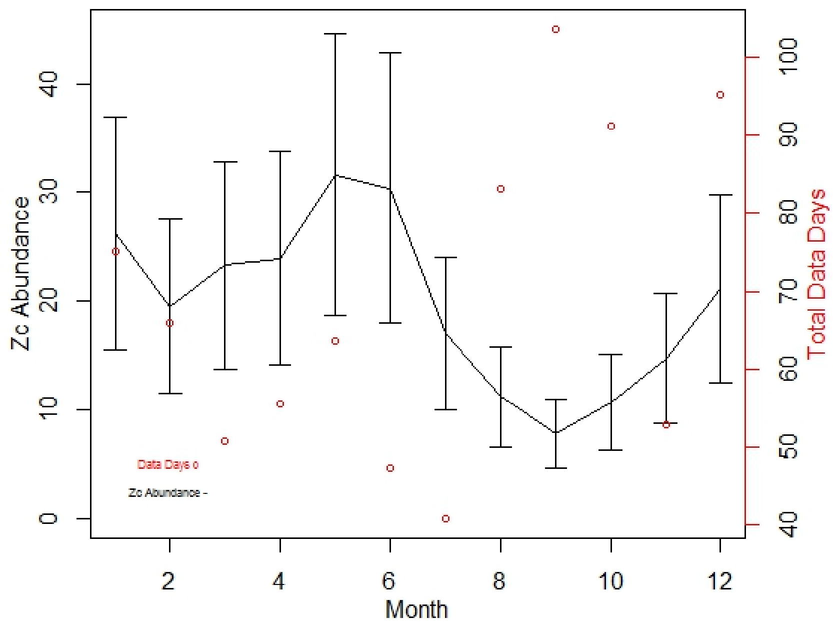

Figure 7. Monthly composite abundance estimate for 2010 – 2014

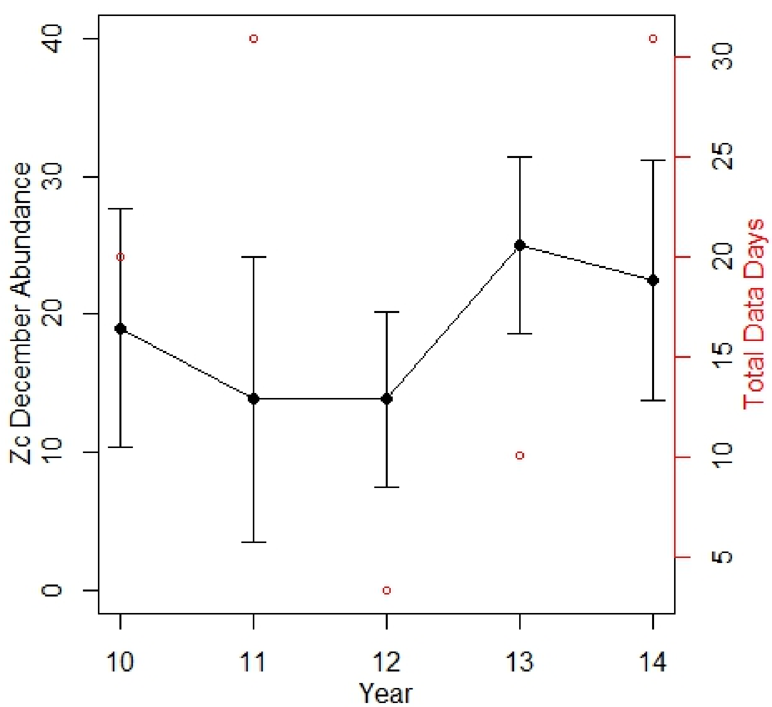

Figure 8. Abundance estimates for years 2010 to 2014 for the month of December.

5. Discussion

5.1 System Summary

Systems have been established at PMRF, SCORE, and AUTEC. All hardware is in place and systematic data collection has begun at PMRF and SCORE.

New hardware has been delivered to PMRF and hardware from PMRF has been repurposed at SCORE and AUTEC. Flash drives have been installed on the systems at PMRF. SCORE will be retrofitted with new drives and the network link replaced with A/D converters as part of the I/A requirements.

A Type Accreditation has been submitted. Final approval is critically necessary to maintain system operation within existing I/A guidelines.

5.2 Abundance Estimation

The M3R program has detected via passive acoustics and visually verified via expert observers Blainville's beaked whales *Md* at AUTEC and PMRF and *Zc* at AUTEC and SCORE. In addition, Gervais' beaked whale (*Mesoplodon europaeus, Me*) has been documented at AUTEC. Beaked whales associate and dive together in groups. They execute deep foraging dives at measurable rates and echolocate only during these dives. Therefore, the detection of beaked whale echolocation clicks indicates a group of animals in a deep foraging dive. If the mean group size and foraging dive rate are known, animal abundance and density can be readily estimated [12] [13].

The M3R capability provided allows long-term monitoring of beaked whales on all three major ranges using the dive counting method developed for *Md* at AUTEC. Tracking trends in abundance over months, seasons, and years will be possible as data become available. Initial estimates of abundance with limited PMRF data from 2010 to 2014 suggest a low but stable abundance of *Md* (Figure 3). The 2010 estimate of abundance (12.34, 6.63-18.055) compares favorably to the semi-automated estimate from 2011 (13.23,7.68-18.78).

Analysis of five years of SCORE data strongly suggest a significant reduction in the abundance of Zc beginning in late spring, extending to early fall with a low in September (Figure 6Figure 6).

Moore & Barlow et al. 2013, suggest a reduction in the population of beaked whales in Southern California [14]. A comparison of abundance for the relatively short period of 2010 -2014 for the month of December shows little evidence of a decline on the range. The estimate ranges from 19 animals in 2010 to 22 animals in 2014.

These findings highlight the need for long-term, continuous monitoring. Over time, M3R passive acoustic data from SCORE will be able to provide a more robust long-term *Zc* abundance estimate for the instrumented Southern California Antisubmarine warfare Range (SOAR) and an estimate of *Md* abundance at PMRF. Such estimates can be cross-validated with those produced using existing photo-ID data via mark-recapture methods.

Additionally, the dive counting method requires an estimate of group size and dive rate. Zc group size is being derived from visual sighting data from collaborating on-water partners [9]. Dive rate is being measured via depth recording mid-term satellite tags [15, 17].

These methods are not restricted to beaked whales, but can be adapted as the in-situ call rate statistics become available for other species, including large baleen species. For example, fin whales are routinely detected and localized on SCORE, and were recently detected and visually verified at PMRF. North Atlantic right whales are present near the proposed site of the Undersea Shallow Water Training Range (USWTR). If the call rates for these ESA listed species are known, passive acoustic density estimation methods can be developed, keeping in mind rates may vary between sexes, seasons, locations, and environmental conditions. However, for large baleen species validation of passive acoustic methods via visual surveys is straight forward as compared to cryptic beaked whale species.

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