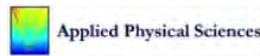


Biological and Behavioral Response Studies of Marine Mammals in Southern California, 2015 ("SOCAL-15")

ANNUAL PROJECT REPORT *26 March 2016*

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1. EXECUTIVE SUMMARY

SOCAL-15 was the anticipated penultimate field effort a multi-institutional scientific research program entitled Southern California Behavioral Response Study (SOCAL-BRS). Based on progress and evolution within this effort, field effort has been conducted and is planned to occur from 2010-2016 in areas of the Southern California Bight. The overall objective is to provide a better understanding of marine mammal behavior and a direct scientific basis to estimate the risk and minimize adverse effects of human sounds, particularly military mid-frequency active sonar (MFAS), on marine mammals. In SOCAL-15, additional basic data were acquired on diving, foraging, social, and vocal behavior of most focal marine mammal species, including measurements in targeted behavioral contexts and extended applications of improved sampling capabilities. There was coordination between SOCAL-15 and operational Navy vessels engaged in training operations to extend earlier integration of real operational sonars in experimental contexts, with two experimental sequences completed in SOCAL-15. SOCAL-BRS continues to be closely coordinated with related research and analysis efforts in the U.S. and Europe, including through a multi-study collaboration on response metrics and statistical analytical methods¹. Many new SOCAL-BRS scientific findings were published since the SOCAL-14 report²; these are discussed below and are freely available on the project website <www.socal-brs.org>.

Like previous field campaigns, SOCAL-15 included an interdisciplinary collaboration of experts in various disciplines of field methods, behavioral analysis, and active and passive acoustic methods. Some but not all specified research objectives for SOCAL-15 were met. Animals of most focal species (except beaked whales) were tagged and experimental exposures and silent control sequences using simulated MFAS were conducted, as well as experiments using full-scale operational Navy MFAS systems. Three operational phases were conducted (supplemented by additional field effort before and after these), during which researchers observed, photographed, and tracked thousands of

¹ Please see: <http://www.creem.st-and.ac.uk/mocha/> for additional information

² Friedlaender, A.S. E.L. Hazen, J.A. Goldbogen, A.K. Stimpert, J. Calambokidis, and B.L. Southall. (2016). Prey-mediated behavioral responses of feeding blue whales in controlled sound exposure experiments. *Ecological Applications*, doi: 10.1002/15-0783.

Goldbogen, J. A., Hazen, E. L., Friedlaender, A. S., Calambokidis, J., DeRuiter, S. L., Stimpert, A. K., Southall, B. L. (2015). Prey density and distribution drive the three-dimensional foraging strategies of the largest filter feeder. *Functional Ecology*, 29: 951-961. doi: 10.1111/1365-2435.12395.

Hazen, E., Friedlaender, A., & Goldbogen, J. A. (2015). Blue whales change their foraging strategies relative to prey density. *Scientific Advances*, e1500469.

Stimpert, A. K., DeRuiter, S. L., Falcone, E. A., Joseph, J., Douglas, A. B., Moretti, D. J., Friedlaender, A. S., Calambokidis, J. Gailey, G., Tyack, P.L., & Goldbogen, J. A. (2015). Sound production and associated behavior of tagged fin whales (*Balaenoptera physalus*) in the Southern California Bight. *Animal Biotelemetry*, 3, 1-12.

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individuals of 13 marine mammal species. Passive acoustic teams detected and tracked beaked whale and dolphin groups and directed tag boats to animal locations where they were tracked and/or tagged. SOCAL-15 included the first operations with three simultaneously operated tagging RHIBs with discrete operating bases and areas.

Eighteen tags (of three kinds) were secured on 17 individual animals of three different focal marine mammal species (fin whale, Risso's dolphin, and blue whale). This included the typical archival high-resolution movement and acoustic tags (DTAGs) used previously in the project, but also included some recently developed dart-attached medium-duration diving, movement, and position-reporting archival tags deployed on several blue whales. We conducted a total of six controlled exposure experiment (CEE) sequences involving six tagged individuals of two marine mammal (blue and fin whales) species equipped with high-resolution suction cup acoustic tags and tracked both visually and acoustically. These included actual Navy MFAS signals, simulated MFAS signals, or silent (no noise) controls as used in previous projects³. Unfortunately, Navy ship availability to support real Navy sonar CEEs was far more limited than expected due both to scheduling and operational conflicts which reduced the opportunities for completing experiments. Additionally fewer target species due to unusual ocean conditions, as well as some tag failures also reduced the success of the more limited opportunities there were during SOCAL-15. Tag failures resulted in the loss of tag data for three experimental sequences, although visual survey focal follow data was obtained for these experiments. Changes in behavior from baseline movement and/or acoustic behavior were measured as a function of sound exposure. Preliminary results based primarily on behavior clearly observable in the field were similar to earlier findings, indicating variable responses (ranging from no observable response to evident temporary avoidance behavior) that depend on species, behavioral contexts during the experiments, and potentially the physical range from animals to sources.

SOCAL-BRS continues to be supported by several organizations within the U.S. Navy (below) seeking better data to inform decision-making, and was closely coordinated with the U.S. National Oceanic and Atmospheric Administration (NOAA). SOCAL-15 was conducted under the authorization of NMFS permit #14534.

³ Southall, B. L., D. Moretti, B. Abraham, J. Calambokidis, P.L. Tyack. (2012). Marine Mammal Behavioral Response Studies in Southern California: Advances in Technology and Experimental Methods. *Marine Technology Society Journal* 46, 46-59.

Southall, B. L., J. Calambokidis, P. Tyack, D. Moretti, A. Friedlaender, E. Falcone, G. Schorr, K. Southall, A. Douglas, S. DeRuiter, J. Goldbogen, J. Barlow. (2014). *Project report: Biological and Behavioral Response Studies of Marine Mammals in Southern California, 2013 (SOCAL-13)*.

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2. PROJECT OBJECTIVES

The overall SOCAL-BRS effort has the following overarching objective:

“SOCAL-BRS is an interdisciplinary, multi-team collaboration designed to *increase understanding* of marine mammal reactions to sound and provide a more robust *scientific basis for estimating impact* of Navy mid-frequency active sonar”

For each field season the SOCAL-BRS research team develops specific research objectives to meet this overarching goal. Some remain constant across seasons, particularly considering the limited baseline behavioral data on behavioral parameters at the high degree of resolution possible using acoustic and movement sensors. Others may change based on results from previous seasons, ongoing analyses, and targeted research priorities. For SOCAL-15, the following specific objectives were explicitly identified before field operations, so that the team and research sponsors can objectively and critically assess success. These included:

- (1) *Obtain baseline behavioral data to support CEE interpretation and conducting CEEs (both realistic sources and scaled sources)***
- (2) *Conduct controlled exposure experiments (CEEs) with both real Navy MFA sources and scaled sources - when full-scale sources unavailable (Species focus to remain flexible based on conditions, but with emphasis on Risso’s dolphins, beaked, and fin whales (blue whales in specific conditions);***
- (3) *Test optimal configuration and areas for subsequent studies involving real Navy MFA sources in contrasting modes***

3. METHODOLOGY AND FOCAL SPECIES

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SOCAL-15 General Methodology

The overall research methods and vessel configuration used in SOCAL-15 field were generally similar to those used in earlier seasons in terms of the broad approach and protocols described in Southall *et al.* (2012; 2013; 2014; 2015), with several exceptions. As in previous field seasons, multi-disciplinary teams used state-of-the-art technologies (and in some cases developed new analytical tools) to conduct different aspects of locating, tagging, and tracking animals and conducting controlled exposure experiments (CEEs). However, we continued to evolve capabilities to work in smaller teams and configurations and to respond rapidly to opportunities to coordinate with Navy training operations.

The field approach involved standard visual sampling methodologies for detecting and tracking marine mammals, typical small boat operations for photo-identification and tagging of research subjects, acoustic monitoring using various sensors (*e.g.*, bottom-mounted hydrophones, towed passive acoustics), and CEEs to determine sound exposure conditions in which behavioral responses may occur. Specialized interdisciplinary teams for the collaborating institutions consisted of highly experienced scientists, engineers, and field personnel.

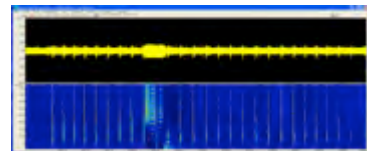
Visual observers, experienced in sighting marine mammals several miles away with specialized binoculars, searched for animals and monitored subjects before, during, and after CEEs. Observers on the central research platform were primarily responsible for locating animals and monitoring during CEEs to fulfill permit requirements for source operations. Visual observers on small boats were primarily responsible for conducting dedicated focal follows of specific animals.



Photo identification was used to identify individuals sighted and involved in CEEs, based on distinct features, scars, and markings. These data are also being used within existing database catalogues for various marine mammal species along the U.S. west coast. [Note: all photos taken during SOCAL-15, including all photos involving animals included in this report, were taken under the authorization and conditions of NMFS permit #14534].



Passive acoustic monitoring utilized different listening platforms and systems to detect and monitor vocalizing animals before and during CEEs. These included a combination of listening sensors on the U.S. Navy SCORE range (the marine mammal monitoring on ranges or “M3R” team),



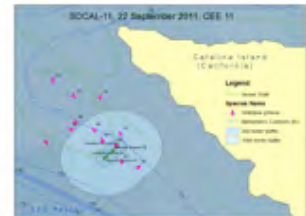
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towed passive acoustics from the central research platform and a separate RHIB operated on the SCORE range (*Interceptor*), and dipping hydrophones and sonobuoys deployed from the *R/V Truth*.



Tagging teams carefully approached and deployed high-resolution acoustic and movement tags with suction cups as well as dart-attached medium-duration dive, movement, and positional sensors from small rigid-hull inflatable boats (RHIBs). RHIB teams provided visual monitoring of focal groups before, during, and after CEEs and recorded behavioral observations in focal follow protocols.

Geographical Information Systems (GIS) tools utilized a variety of data streams (including vessel position, some visual sightings, and geographic/oceanographic data) for real-time depiction on maps. These data were integrated in a software environment called the Whale Identification, Logging Display System (WILD), which provided operational awareness and a time-synchronized archive of some SOCAL-15 data.



Sound source engineers operated compact sound projectors capable of producing relatively high amplitude simulated MFA sonar signals when Navy vessels were unavailable. For SOCAL-15 the 10-element version with smaller top-side control system first tested in was used.



2013



Fisheries acoustics biologists obtained measurements of prey distribution in relation to high-resolution whale behavior measured using movement tags, and as a covariate for response analysis. These sampling procedures were only used during work with mysticete cetaceans and involved high frequency sounds above their likely hearing ranges. Recent analyses currently being published demonstrate the profound increase in the ability to understand and describe whale behavior and potential responses to CEE stimuli with the addition of these methods.



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SOCAL-15 successfully coordinated CEEs with Navy vessels operating in the context of regularly planned training operations on two occasions. These included coordination with the *USS William P. Lawrence* in March and the *USS Russell* in August.

SOCAL-15 Focal Species and Permit Requirements

This project was conducted under the terms of U.S. National Marine Fisheries Service (NMFS) research permit #14534-2 (issued to Ned Cyr; principal investigator: B. Southall) and under the terms of a federal consistency determination of the California Coastal Commission. As authorized within permit #14534 (and modifications #14534-1 and #14534-2), a number of “focal” marine mammal species were directly studied. For each species, a number of “takes” of different types were permitted for different activities, including behavioral observation, close approach for photo ID, attachment high-resolution archival acoustic and movement tags, and sound exposure from vessels, prey-imaging active sonars, and experimental sounds used in CEEs. Some additional research activities, including deployment of dart-attached archival tags, were also conducted under NMFS Permit #16111 issued to John Calambokidis, Cascadia Research.

The following species were authorized as “focal” species for tagging and CEEs under NMFS permit #14534-2 (those in **bold** were identified as high priority species in SOCAL-14): **blue whale (*Balaenoptera musculus*)**, **fin whale (*Balaenoptera physalus*)**, humpback whale (*Megaptera novaeangliae*), minke whale (*Balaenoptera acutorostrata*), sperm whale (*Physeter macrocephalus*), **Cuvier’s beaked whale (*Ziphius cavirostris*)**, **Baird’s beaked whale (*Berardius bairdii*)**, Blainville’s beaked whale (*Mesoplodon densirostris*), short-finned pilot whale (*Globicephala macrorhynchus*), **Risso’s dolphin (*Grampus griseus*)**, killer whale (*Orcinus orca*), bottlenose dolphin (*Tursiops truncatus*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), short or long-beaked common dolphin (*Delphinus* sp.), northern right whale dolphin (*Lissodelphis borealis*), California sea lion (*Zalophus californianus*), northern elephant seal (*Mirounga angustirostris*), and harbor seal (*Phoca vitulina*). Almost all high-priority focal species, as well as some secondary priority species, were encountered and included in the overall research effort.

4. OPERATIONAL AREAS & TIMING

The SOCAL-BRS general operational area includes both southern and northern “inshore” areas around southern California, and an offshore area that includes the U.S. Navy’s SCORE range (see figure to right). During SOCAL-BRS, operations have occurred throughout this region, with all sound transmissions occurring at

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least 1 nm from shore in any area and at least 3 nm from any landmass within the CINMS.

SOCAL-15 was conducted in three experimental phases, each involving different configurations and operational areas, with additional field effort conducted supplementing these phases involving testing equipment, deploying and recovering dart-attached

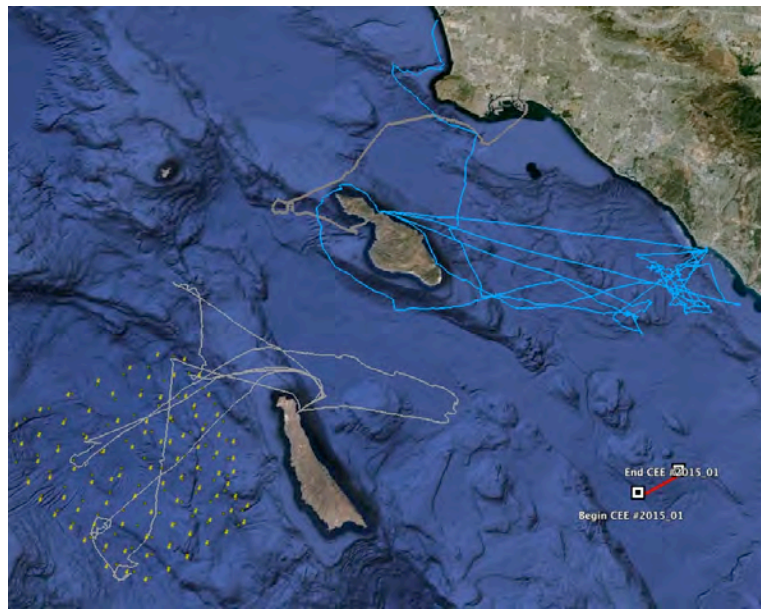


tags, and having teams on site in case of Navy ship availability. For phases I and III, small periods (“Phases I II”) the slightly larger SOCAL-BRS configuration of research vessels and personnel, the *R/V Truth* (right: a ~23m dive charter vessel converted for use in this research project with a specialized observation platform and other modifications) was used as a base of operations in conjunction with the two tagging RHIBs. A small field team configuration based exclusively from RHIB platforms was scheduled for later in the year, but this did not occur as the planned coordination with Navy training during this period was not possible. Periods of operations, vessel configurations, and maps showing overall survey effort for each of these four periods are given below. Details regarding tagging and CEE results are provided later in this report.



15-20 March 2015: SOCAL-15 PHASE I

Operations focused on tagging to measure baseline behavior and real Navy ship source CEEs, through coordination with the *USS Wm. P. Lawrence* that was in the field conducting regularly planned training operations during this period. A SOCAL-BRS field contingent of six was based from two RHIBs working from shore bases on the mainland as well as Catalina and San Clemente Islands during this period. The M3R base of operations at the SCORE command center was manned to provide real-time acoustic detection and tracking capabilities for the SCORE range for periods when weather permitted

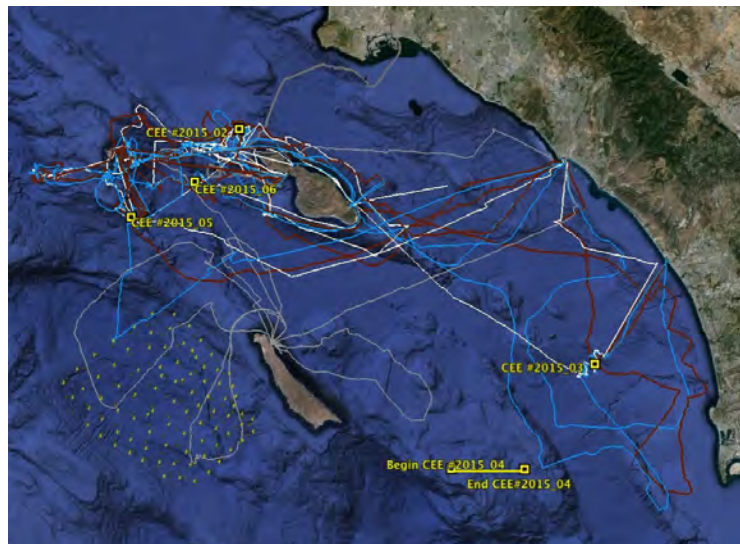


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offshore. The tracks of both tagging RHIBs are shown in the map to the right (*Musculus* in blue and *Physalus* in grey) as well as the location of the one CEE conducted in this period (CEE #2015_01). *Physalus* was generally based from San Clemente Island and worked offshore areas including the SCORE range to the west of the island (hydrophone positions in yellow). *Musculus* generally worked more inshore areas between Catalina and the mainland, basing from both locations. The beginning and end position of the *USS Lawrence* while transmitting active sonar during this experiment is indicated, which was positioned relative to a blue whale located to the north of the transmission location (discussed more below). Conditions were generally good for most of this period, better inshore, and three of four focal species were both sighted and tagged (fin and blue whales and Risso's dolphin). This included several short-duration tag deployments and several during periods when coordination with the Navy ship was not possible. On one occasion, a tagged fin whale was successfully included in a CEE in coordination with the *USS Lawrence* (CEE #2015-01).

16 - 25 August 2015: SOCAL-15 PHASE II

Operations focused on tagging to measure baseline behavior and real Navy ship source CEEs, through coordination with the *USS Russel* that was in the field conducting regularly planned training operations during this period; simulated sonar CEEs were a secondary priority conducted on several occasions when coordination with the *USS Russel* were not possible. A full complement of SOCAL-BRS research vessels and field personnel (21 total) was available for SOCAL-15 phase II. This included the *R/V Truth* that served as central coordination and housing for most of the field team, as well as visual, sound source, prey mapping, and data archive teams. For the first time during SOCAL-BRS three tagging RHIBs were operated simultaneously (*Ziphid*, *Musculus*, and *Physalus*). Additionally, the M3R base of operations at the SCORE command center was manned to provide real-time acoustic detection and tracking capabilities for the SCORE range and to provide communication support with operational Navy vessels. Tracks of the *Truth* (white) during this period and all three tagging RHIBs are shown in the map to the right (*Musculus* in blue, *Ziphid* in red, *Physalus* in grey) as well as the location



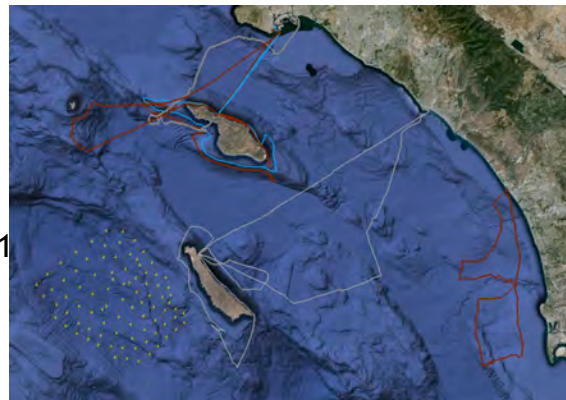
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of the five CEEs conducted in this period (CEE #2015_02 through CEE #2015_06). *Physalus* was based from San Clemente Island and generally worked offshore areas including the SCORE range to the west of the island (hydrophone positions in yellow). *Musculus* and Ziphid were based with the *Truth* and worked together in offshore areas as possible and some inshore areas between Catalina and the mainland. Weather conditions were generally good for most of this period, allowing workable conditions both inshore and offshore on most working days. However, as the initial stages of the strong 2015 El Niño patterns were beginning to be seen across the southern California Bight, the distribution of focal species was significantly affected. This resulted in much more offshore distribution of baleen whales during this period, which is reflected in the tracks as well as the locations of CEEs with blue and fin whales. As in phase I, three of four focal species were both sighted and tagged (fin and blue whales and Risso's dolphin). This again included several short-duration tag deployments and several during periods when coordination with the Navy ship was not possible. Two experimental sequences with simulated MFAS (#2015_02 and #2015_06) were completed as well as two control (no sonar) experiments (#2015_03 and #2015_05) during periods with coordination with the Navy ship was not possible. On one occasion, a tagged blue whale was successfully included in a CEE in coordination with the *USS Russel* (CEE #2015-04). Unfortunately, tag failures resulted in the loss of archival tags and their data for three CEEs (-03, -04, and -05), although visual focal follow data from these periods were collected. In addition, through a coordination with several companion research projects coordinated with SOCAL-BRS, several newly developed medium-term, dart-attached archival tags measuring detailed diving, moving, and position were deployed on blue and fin whales, several of which were on subjects exposed incidentally to sonar at known locations.

5-8 October 2015: SOCAL-15 PHASE III

Operations focused on tagging to measure baseline behavior and real Navy ship source CEEs, through coordination with the *USS Howard* that was in the field conducting regularly planned training operations during this period. A SOCAL-BRS field contingent of eight was based from three RHIBs working from shore bases on the mainland as well as Catalina and San Clemente Islands during this period. The M3R base of operations at the SCORE command center was manned to provide real-time acoustic detection and tracking capabilities for the SCORE range for periods when weather permitted offshore.

Tracks of all three tagging RHIBs are shown in the map to the right (*Musculus* in blue, *Ziphid* in red, *Physalus* in grey). *Physalus* was based from San Clemente Island and



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generally worked offshore areas around the island, though not actually on the SCORE range to the west of the island (hydrophone positions in yellow) during this period. *Musculus* and *Ziphid* were based out of several mainland ports and worked several days around Catalina. Weather conditions were generally good for most of this period, allowing workable conditions both inshore and offshore on most working days. However, the offshore distribution of baleen whales continued and was even stronger during this period, such that while some scouting in nearshore areas was conducted the animals that were sighted and tagged were well offshore. Tagging and CEEs during this periods were limited by both the limited detections of focal species as well as limited availability of opportunities to coordinate with the Navy ship. On one occasion a blue whale was tagged and a CEE with the *Howard* was designed, but this was not successfully completed. During this tag deployment, however, incidental MFAS was received on the tag from sources at known positions, which is being analyzed as an incidental sonar exposure sequence. As a result of limited opportunities to coordinate with the Navy ship, field operations for this period were terminated several days earlier than planned. A fourth phase of SOCAL-15 was planned but not conducted as coordination with a fourth ship was not possible.

5. VISUAL SURVEY RESULTS

Trained and experienced marine mammal visual observers were used on both RHIBs and the *Truth* during all phases of SOCAL-15. Visual observers were on duty from all platforms during essentially all daylight hours when weather and sea conditions permitted operating in three different operational modes, including:

Survey Mode - a general search mode to locate possible focal individual(s)

Focal Follow Mode - dedicated tracking of specific individual(s)

Mitigation Mode - visual survey of an area before, during, and just after CEEs to meet specified safety protocols and determine incidental “takes” of non-focal marine mammals for compliance with research permits.

On the *Truth*, a rotating team of 2-3 trained and experienced visual observers were based on an elevated (~6m) observation platform with a 360° field of view. These observers used handheld reticle binoculars (7x50 Fujinon and 15x80 Fujinon) and an angle board to determine range and bearing of sightings for entry into the specialized geospatial software system (WILD - described above). The *Truth* visual observers were most commonly in survey mode, searching for candidate species for potential tagging, communicating information about

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sighting between platforms, and in some cases obtaining photo ID samples. Prior to selection of focal animals or groups as subjects for tagging or focal follow, RHIB observers searched widely in survey mode as well. Once a focal follow was initiated, typically after a subject was tagged, observers from the RHIBs used primarily naked eye observations given their range to focal animals (~250 m).

In almost all cases, visual observers from the RHIBs conducted conventional focal follows reporting the position and behavior of tagged individuals before, during, and after CEEs. The only exception to this was situations where a particular target of interest was spotted first by the *Truth*, who then vectored the RHIBs in; or situations where a high-priority and difficult to track target (beaked whales) was being followed and the *Truth* was a superior visual platform. Individuals and/or groups that were re-sighted were coded accordingly within WILD, keyed to the RHIB sighting numbers where appropriate. In all focal follows, the following behavioral observations were collected:

- Initial surface and terminal dive times of specific focal follow animal or focal group
- Swim direction relative to vessel and sound source
- General behavior - slow/fast travel, milling, feeding, dis/affiliation, tail slap, breach etc.
- Group envelope (spatial extent of group)
- Age class(es)

This variation of conventional focal follow protocols enabled *Truth* observers to accurately track individual animals or groups of interest (particularly high priority focal individuals like beaked whales, often in support of RHIBs that were less successful in seeing them) and to provide a reliable estimate of potential incidental exposures for permit requirements during CEEs. Additionally, some efforts were made to test protocols for focal follows of groups of smaller odontocete cetaceans from the *Truth* in preparation for potential sound playbacks in which animals were not tagged, although few dedicated trials of these procedures were performed. However, in several cases, focal follows from the RHIBs were conducted on focal groups that did not include tagged individuals.

The *Truth* maintained position ~1000m from tagged focal animals before, during, and after CEEs as specified in operational protocols, while RHIB observers maintained ~250m range and were responsible for maintaining focal

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follows to provide information about range, bearing and behavior of specific individuals/groups. Additionally, RHIBs were in constant communication with the *Truth* and thus contributed to mitigation mode during CEEs as well. Visual observers across all platforms ensured all specified shutdown conditions were met by monitoring the specified safety radius and providing 360° visual coverage for any abnormal behavioral responses by focal or non-focal animals. Visual survey results for SOCAL-15 for the *Truth* and RHIB visual observers, are given below for all platforms, operational effort phases, and observational modes.

SOCAL-14 Results from Visual Observer Team - all Platforms

Survey effort days during SOCAL-15 field operations:

SOCAL-15 Phase	<i>RHIB Ziphid</i>	<i>RHIB Musculus</i>	<i>RHIB Physalus</i>	<i>R/V Truth</i>
I	-	5	4	-
II	10	10	9	10
III	4	2	4	-

Total marine mammal sighting events for SOCAL-15 field operations for all phases (best estimate of total numbers in parentheses)

SOCAL-15 Phase	<i>RHIB Ziphid</i>	<i>RHIB Musculus</i>	<i>RHIB Physalus</i>	<i>R/V Truth</i>
I	-	15 (25)	8 (30)	-
II	30 (280)	41 (515)	16 (52)	52 (844)
III	7 (12)	1 (3)	4 (10)	-

A total of 13 marine mammal species were confirmed across all platforms
(common names given below)

Blue whale

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Fin whale

Minke whale
Humpback whale

Cuvier's beaked whale

Long-beaked common dolphin

Short-beaked common dolphin

Delphinus sp.

Risso's dolphin

Bottlenose dolphin

Elephant seal

Pacific harbor seal

California sea lion

In certain cases (including Risso's dolphin CEEs), additional visual group sampling methodologies were applied. The objectives of these efforts were to compare and complement the standard focal follow measures typically used (focused more on group movement and general behavior) with a focal-individual group sampling method with more detailed observations relating to social behavior. In these cases, the following data were obtained (each minute for tracking data, every two minutes for behavioral data) for groups of animals:

- Range and bearing to group; group swim direction
- Group size (low/best/high)
- Calf presence (binary)
- # of subgroups (categorical)
- Group spacing (categorical)
- Group shape (categorical)
- Distance between sub-groups (categorical)
- Display events (binary)
- Behavioral state

6. TOWED PASSIVE ACOUSTIC MONITORING

Overview and Methods

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The purpose of the Passive Acoustic Monitoring (PAM) component of the SOCAL-BRS is to find beaked whales and sperm whales as test subjects. Secondary objectives include: detecting other marine mammals in the study area; and recording and measuring test vessel noise, ambient noise, and the simulated Navy sonar signal at varying distances from the source vessel.

During SOCAL-15, PAM efforts included primarily the coordination with the M3R team on the SCORE range and sonobuoy and remote-deployed hydrophones from the *Truth* during Phase II. Additionally, feasibility testing of operating the NOAA PAM system from RHIBs operated off San Clemente Island was conducted. During this field testing, towed PAM systems were operated from a Navy RHIB (Interceptor) on and around the SCORE range. Beaked whales initially detected acoustically on the SCORE range were successfully detected using this PAM system by vectoring the Interceptor to the detection location. Common dolphins were also successfully detected using the towed PAM system on several locations. These trial deployments demonstrated the feasibility of this approach and provided a number of lessons-learned to support subsequent operational deployments in support of CEEs. A separate detailed report from NOAA SWFSC discusses these in greater detail. This system was scheduled to be used in phase IV of SOCAL-15 operations in late October-early November but this field period was not conducted.

7. SUMMARY OF TAG DEPLOYMENTS

A similar suite of acoustic and movement tags were used in SOCAL-15 as in previous projects, each with somewhat different capabilities and thus intended functions. These included:

DTAGs - designed and supplied by WHOI collaborators⁴, these tags are attached with suction cups for up to tens of hours, recording digital sound (variable bandwidth from ~100Hz up to 240 kHz) as well as depth and 3-D accelerometer and magnetometer data. Version 3 DTAGs were used in SOCAL-14.

Dart-attached archival - This represented a relatively new configuration based around the Wildlife Computer *TDR-10Fs*⁵ deployed in past years that recorded depth and GPS position but modified to include a satellite transmitter, a high sample rate accelerometer, magnetometer, and gyroscope, and now attached with short darts to achieve durations of up to 3 weeks.



⁴ Johnson, M. P., and P. L. Tyack. 2003. A Digital Acoustic Recording Tag for Measuring the Response of Wild Marine Mammals to Sound. *IEEE Journal of Oceanic Engineering* 28:3-12.

⁵ http://www.wildlifecomputers.com/Media/MDS/TDR10_FastlocGPSBackmountSuite.pdf

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*ACOUSONDES*⁶ - these suction cup-attached tags from Greeneridge Sciences, Inc. provide digital sound (variable bandwidth from ~20Hz to 116 kHz), depth, temperature, pitch and roll angles. These were available but not deployed in SOCAL-15.

Depending on the focal species, environmental conditions, timing, and other practical considerations, different combinations of these tags were used in different circumstances, as well as custom video tag deployments on two whales as a secondary objective.

Seventeen tags (of three kinds) were secured on 18 individual animals of three different marine mammal species during all phases of SOCAL-14. These primarily included blue and fin whales with several instances of multiple tags deployed simultaneously. Deployments on Risso's dolphins were almost all very short in duration. Unfortunately, no beaked whales were tagged in SOCAL-15. A summary of the overall tag deployments by species and tag type is given below, followed by a breakdown of attachment type and duration (for high-resolution DTAGs that were the primary tag objective) by individual. A total of over 40 hours of high-resolution acoustic and movement tag data were collected across all deployments.

TOTAL SOCAL-15	17 individuals of 3 species (with 18 tags of 3 types)
Risso's dolphins:	4 individuals (4 DTAG3)
Fin Whales:	6 individuals (5 DTAG3; 1 medium-term TDR)
Blue Whales:	7 individuals (5 DTAG3; 2 medium-term TDR; 1 video tag)

⁶ <http://www.acousonde.com/>

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Phase I (RHIBs-only)

16-Mar	2:53	Fin Whale	bp15_075a
16-Mar	0:01	Rissos Dolphin	n/a
17-Mar	3:19	Blue Whale	bw15_076a
17-Mar	0:01	Rissos Dolphin	n/a
20-Mar	0:25	Rissos Dolphin	gg15_079a
20-Mar	4:26	Fin Whale	bp15_079a

Phase II (TRUTH plus RHIBs)

16-Aug	0:01	Rissos Dolphin	n/a
17-Aug	5:35	Fin Whale	bp15_229a
18-Aug	n/a	Blue Whale	bw15_230a
19-Aug	n/a	Blue Whale	bw15_231a
19-Aug	n/a	Fin Whale	bp15_231a
20-Aug	2:33	Blue Whale	bw15_232a
20-Aug	TAG LOST	Blue Whale	bw15_232a
20-Aug	TAG LOST	Blue Whale	bw15_232a
22-Aug	TAG LOST	Blue Whale	bw15_234a
23-Aug	13:00	Blue Whale	bw15_234_video
23-Aug	0:42	Fin Whale	bw15_235a
24-Aug	4:19	Fin Whale	bw15_236a

Phase III (RHIBs-only)

6-Oct	5:30	Blue Whale	bw15_279a
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8. CONTROLLED EXPOSURE EXPERIMENTS (CEEs)

General Methodology and Sound types

CEEs were conducted using similar methods and sound types to those used in earlier phases of the SOCAL-BRS project⁷. Experimental protocols are based on well-established methods of measuring behavioral responses to various stimuli using a before, during, after (A-B-A) paradigm. These are described briefly here with emphasis on methodological differences from previous field seasons.

Numerous safety protocols were again implemented regarding conditions required to initiate and continue sound exposures, in order to ensure the experiments could be completed safely without causing harm to the animals being investigated or others in the area. All possible means of monitoring animals (visual, acoustic tags, other passive acoustic sensors) were used to observe movement and acoustic behavior in a baseline (“pre-exposure”) period. Given that specific criteria were met regarding the operational area (described below), specific and controlled sound “exposure” sequences (using the simulated MFAS and no noise control sequences described below) were initiated using explicit transmission and monitoring/safety shut-down protocols (also see below). Following the cessation of sound transmissions, monitoring was sustained during a “post-exposure” period.

As described above, for SOCAL-15 experimental signals used in CEEs were from either simulated or real Navy MFAS sound sources. Simulated MFAS signals were projected from the 10-element vertical line array source described above and had a 0.5s linear frequency modulated upswEEP from 3.5 to 3.6 kHz, a 0.5s constant frequency tone at 3.75 kHz, a 0.1s silent interval, and a 0.5s constant frequency tone at 4.05 kHz. Sounds were nominally transmitted once every 25s (to mimic the output characteristics typical of many 53C systems), beginning at a broadband source level of 160 dB re: 1μPa (RMS) and ramping up 3 dB per transmission to a maximum transmitted source level of 210 dB re: 1μPa.

Full no-noise “control” sequences were conducted as well, which included a baseline period, a “mock” exposure (sound source deployed but not transmitting), and a “post-exposure” sequence. These were conducted within a balanced sequence of simulated MFAS CEEs determined *a priori* and nominally blind to visual observers (simulated MFA transmissions were audible on the Truth) and RHIB personnel (who are ultimately responsible for conducting focal follows and to whom transmissions were typically not audible).

CEE Protocols and Shut-Down Criteria

⁷ Southall, B. L., D. Moretti, B. Abraham, J. Calambokidis, P.L. Tyack. (2012). Marine Mammal Behavioral Response Studies in Southern California: Advances in Technology and Experimental Methods. *Marine Technology Society Journal* 46, 46-59.

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Specific protocols for conducting CEEs in SOCAL-15 were very similar to previous efforts and were specified in the project test plan prior to the field season. These are described below, including conditions required to begin, continue/terminate, and monitor the experimental area following CEEs. The following conditions were required to be met prior to all CEEs:

- Tags must be attached for a sufficient duration to reduce attachment disturbance effects and to obtain a reasonable amount of baseline behavioral data (using tags and visual observations). For mysticetes and most odontocetes this period was a minimum of 45 minutes, ideally two hours; this was at least one deep foraging dive and complete surface sequence for beaked whales.
- Confirm that *no calves in group are neonates*, as defined within the NMFS scientific research permit (presence of fetal folds for non-ESA listed species and <6 months for ESA-listed species).
- Determine that operational conditions (e.g., weather, location of non-SOCAL-BRS vessels) are likely to allow for successful completion of CEE and interpretation of results, as well as post-exposure monitoring.
- Determine that the scaled sound source is not within 1nm of any landmass or within 3nm from land within the Channel Islands National Marine Sanctuary. Determine that real MFA sources are no closer than 3 nm to shore (typically much further given where most training operations occur), are not vectored either directly perpendicular to or parallel to shore, and do not transmit in canyons.

Provided that these conditions were met, as agreed upon by the chief scientist and co-investigators in the field, researchers would then proceed with CEEs according to the following procedures:

SIMULATED MFAS SOURCE CEEs

- Position source vessel ~1000m from the focal group or animal, taking into account group movement/distribution, to the extent possible.
- Reduce engine propulsion noise and speed, as much as possible.
- Deploy source to specified 20m depth.
- Determine that no marine mammals are present within 200m of source vessel.
- Initiate sound transmissions at a source level of 160 dB re: 1 μ Pa, one transmission every 25s ramped up by 3 dB per transmission to maximum output level.
- Maintain transmissions once each 25s at the maximum source level, unless any contra-indicators require shut-down (see below), for a total maximum transmission time (including ramp-up) of 30 min.

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REAL NAVY MFAS SOURCE CEEs

- Position Navy vessel at an appropriate range and course trajectory from the focal group or animal to meet the specified received level objectives for each species group (110-130 dB RMS for beaked whales; 120-150 dB RMS for all other species) based on *in situ* sound propagation modeling, taking into account group movement/distribution, to the extent possible.
- RHIB tracking teams maintain focal follows and observe any other animals in the area.
- Navy vessels operate under all monitoring and mitigation requirements for normal authorized training operations.
- Initiate MFAS transmissions following final coordination with field teams and transmit at 8 kt speed holding a steady course directed generally (but not directly) toward focal (tagged) animals.
- Maintain transmissions, unless any contra-indicators require shut-down (see below), for a total maximum transmission time of 60 min.

One exposure type was used per focal individual/group, with sufficient pre-exposure baseline and as much post-exposure “recovery” as possible. A pseudorandom sequence between exposure and control (no noise) CEEs within operational areas was balanced as possible when CEEs occurred in the same area on sequential days to meet the experimental design and reduce the potential that prior incidental exposures might affect responses in focal animals.

During CEEs, safety shut-down protocols were used, such that any of the following events resulted in the immediate termination of scaled sound exposures:

- *Any marine mammal inside 200m shut-down zone* around scaled source vessel during transmissions.
- Visual detection from source boat or RHIBs of either the focal animal(s) or incidentally-exposed marine mammals exhibiting the following behaviors⁸:
 - o *Directed, high speed or other abnormal swimming behavior (at surface), especially toward shore.*
 - o *Unusual and abnormal surface/subsurface behavior involving apparent disorientation and confusion or dramatic changes in group cohesion.*
- Controlled sound exposures were conducted with focal groups that included dependent calves that were not neonates (no fetal folds for non-ESA

⁸ None of these behaviors have been observed in any CEE sequence during SOCAL-BRS.

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listed species). However, if the *mother-calf pair had become clearly separated during transmissions* (as determined by one of the principal investigators based on the input of trained marine mammal observers) CEEs would have been terminated.

- Any Navy vessel MFAS would occur in full compliance with standard monitoring and mitigation requirements.

After CEEs, the following post-exposure monitoring was conducted:

- Either the scaled source boat and/or RHIB visual teams maintained visual monitoring (and passive acoustic monitoring (PAM), if applicable/possible) of focal groups for at least one hour post-CEE, and VHF radio monitoring for as long as possible;
- Post-CEE visual monitoring of the sound playback area was conducted by both the visual observers on the source vessel and the RHIBs, who maintained focal follow of the tagged animal(s) during the post-exposure period. These observations were maintained within the playback area for a minimum of 45 minutes and typically longer.

Summary of SOCAL-15 CEEs

During experimental phases I and II of SOCAL-15, CEEs were successfully conducted using either real Navy MFAS, simulated MFAS or no noise control “exposures.” CEEs were successfully completed with six individuals of two marine mammal species (fin whale (3) and blue whale (3)). No SOCAL-15 CEEs were terminated during the CEE prior to the maximum transmission period as the result of animals behaving aberrantly (according to criteria specified above) or by entering the 200m “shut-down” zone around the scaled sound source.

A chronological list of the CEE sequences by SOCAL-15 experimental phase is given below, showing date, CEE number, sound exposure type and duration, and a brief description with a tagged animal dive profile and sound exposure received level (where applicable - and possible given the loss of several tags). Maps showing the location of each CEE are given (in section 4) above.

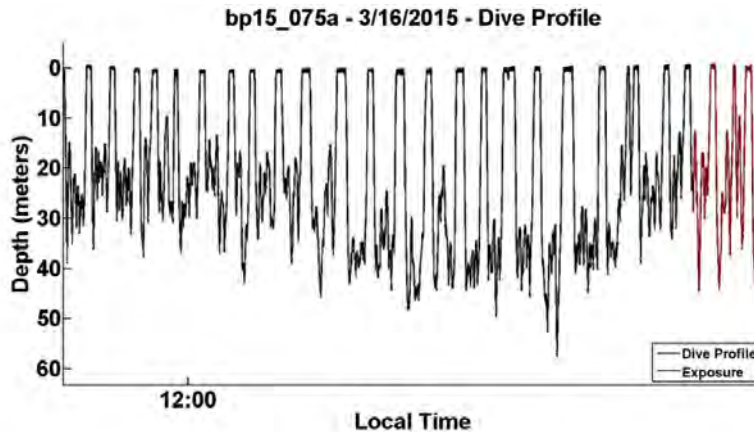
SOCAL-15 - CEE Sequences

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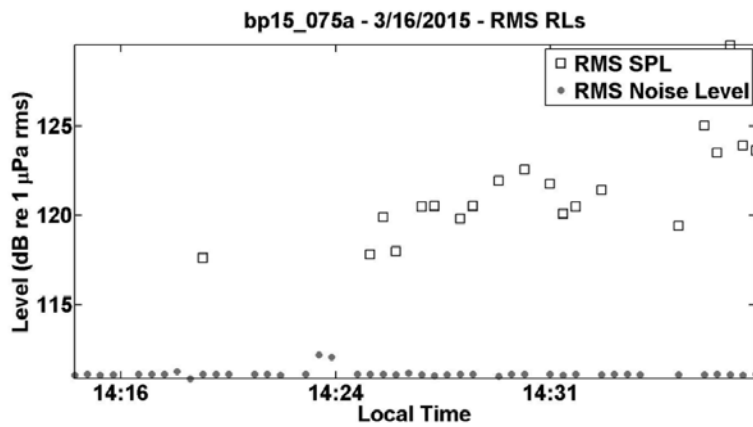
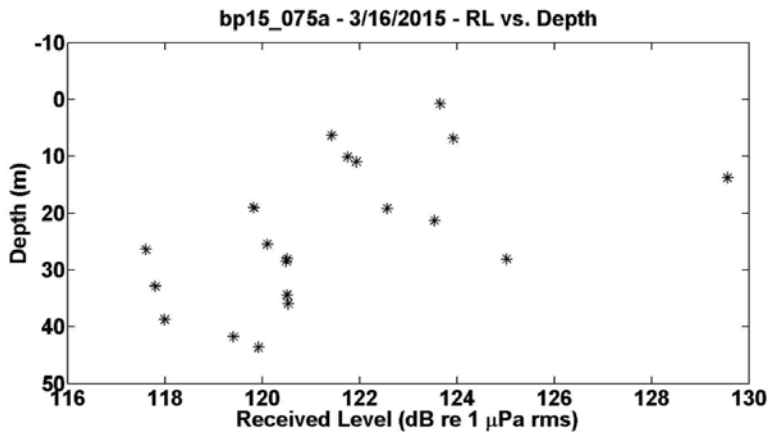
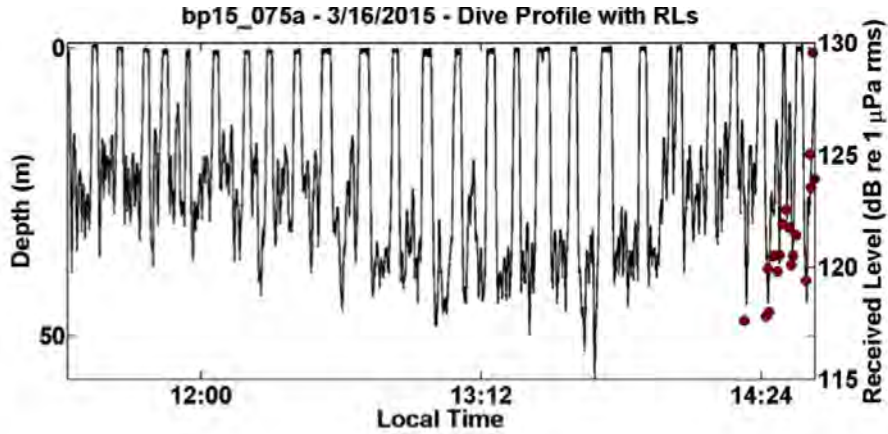
Date	Species	Animal ID	CEE #	CEE Type	CEE TIME (local PDT)	CEE Duration (min)
Phase I (RHIBs-only)						
16-Mar	Fin Whale	bp15_075a	#2015_01	REAL MFA (USS LAWRENCE)	1414-1520	~20
Phase II (TRUTH plus RHIBs)						
17-Aug	Fin Whale	bp15_229a	#2015_02	SIMULATED MFA	1241-1311	30
20-Aug	Blue Whale	bw15_232a	#2015_03	CONTROL	1645-1715	30
20-Aug	Blue Whale	bw15_232a	#2015_04	REAL SHIP MFA (USS Russet)	1754-1829	35
22-Aug	Blue Whale	bw15_234a	#2015_05	CONTROL	1716-1746	30
24-Aug	Fin Whale	bw15_236a	#2015_06	SIMULATED MFA	1427-1457	30

CEE # 2015-01

- DATE and TIME: **16 March 2015 (1625-1645)**
- LOCATION (Source at start of CEE): **SW of Dana Point (32.937; -117.7897)**
- FOCAL SPECIES: **FIN WHALE**
- INDIVIDUAL ID(s): **bp15_077a**
- CEE TYPE (DURATION): **REAL MFAS from USS Lawrence (20:00)**
- SUMMARY: Fin whale tagged in a loose feeding aggregation of 5-6 animals was the focal animal. Source-animal range was ~18-14 nm during the CEE, determined a priori based on sound propagation modeling given the ship and animal position prior to the CEE. No prey mapping sequences were conducted for this CEE sequence.



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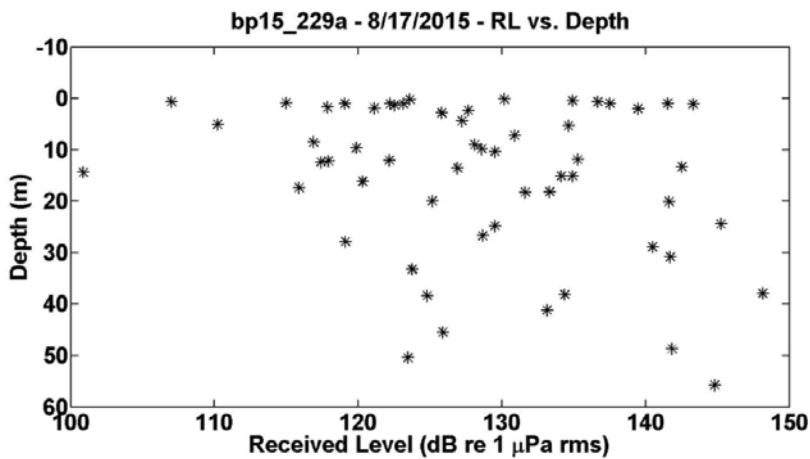
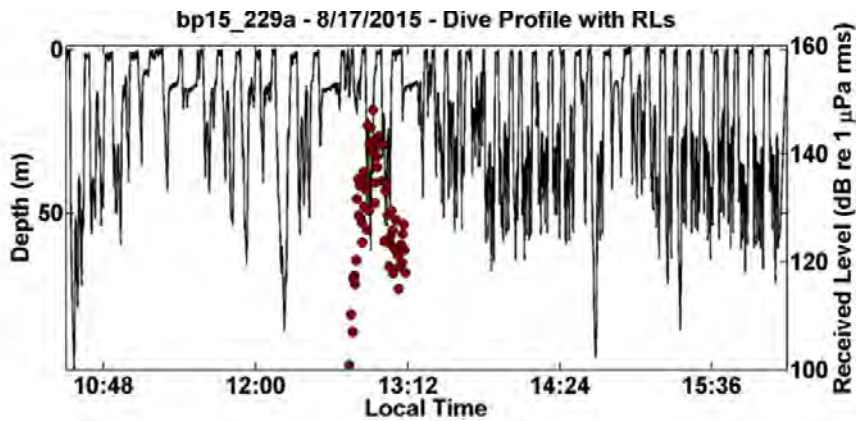


CEE # 2015-02

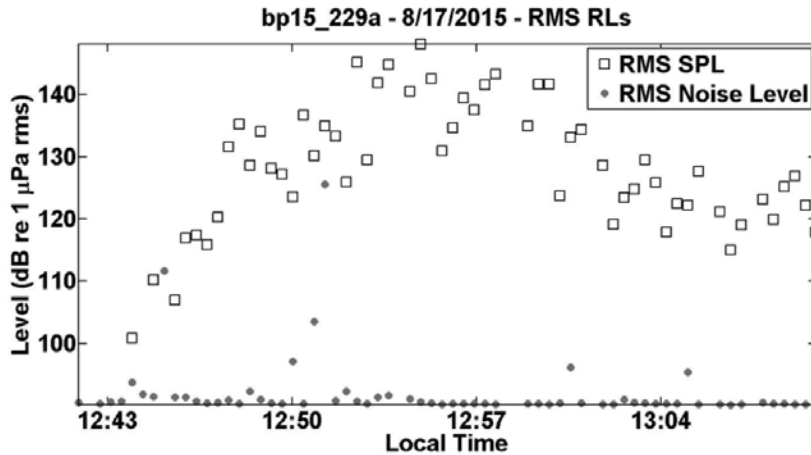
- DATE and TIME: 17 Aug 2015 (1241-1311)
- LOCATION (Source at start of CEE): NW of Catalina (33.5371; -118.6522)

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- FOCAL SPECIES: FIN WHALE
- INDIVIDUAL ID(s): bp15_229a
- CEE TYPE (DURATION): **SIMULATED MFAS (30:00)**
- SUMMARY: Mixed species (blue and fin whales) feeding aggregation in which one fin whale was tagged for sufficient time to conduct a CEE. Navy ship unavailable to coordinate with SOCAL-BRS so a simulated CEE was conducted. Prey mapping was conducted before but conditions were too rough afterwards to complete post-exposure prey mapping.



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CEE # 2015-03

- DATE and TIME: **20 August 2015 (1645-1715)**
- LOCATION (Source at start of CEE): **South of Dana Point (32.9583; -117.6116)**
- FOCAL SPECIES: **BLUE WHALE**
- INDIVIDUAL ID(s): **bw15_232a**
- CEE TYPE (DURATION): **SILENT CONTROL (30:00)**
- SUMMARY: Single blue whale tagged with no other animals in the immediate vicinity. Navy ship unavailable to coordinate with SOCAL-BRS so a complete silent control sequence with full focal follow was conducted. Full prey mapping sequences were conducted before and following the silent control, followed by the exposure below (CEE #2015_04) when the Navy ship became available. NOTE: unfortunately the DTAG deployed on this whale had a transmitter failure and was not recovered.

CEE # 2015-04

- DATE and TIME: **20 August 2015 (1754-1829)**
- LOCATION (Source at start of CEE): **South of Dana Point (32.707; -118.0300)**
- FOCAL SPECIES: **BLUE WHALE**

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- INDIVIDUAL ID(s): **bw15_232a**
- CEE TYPE (DURATION): **REAL MFAS from *USS Russell* (35:00)**
- SUMMARY: Same single blue whale tagged as in #2015_03 with no other animals in the immediate vicinity. Navy ship became available to coordinate with SOCAL-BRS so following silent control sequence a real ship CEE was conducted. No additional prey mapping sequences were conducted before or following the silent control. NOTE: unfortunately the DTAG deployed on this whale had a transmitter failure and was not recovered.

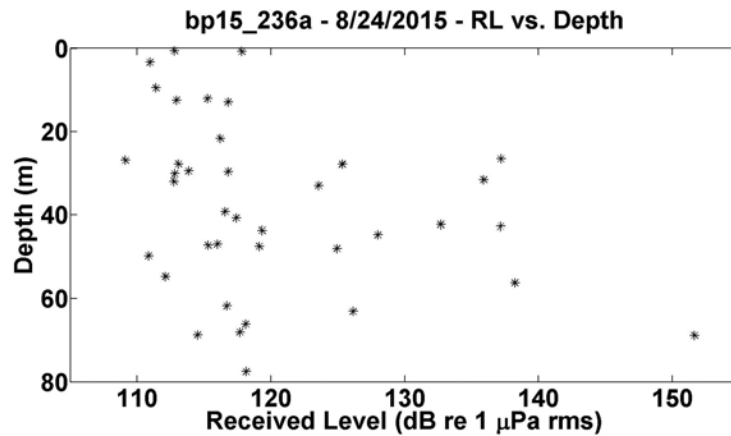
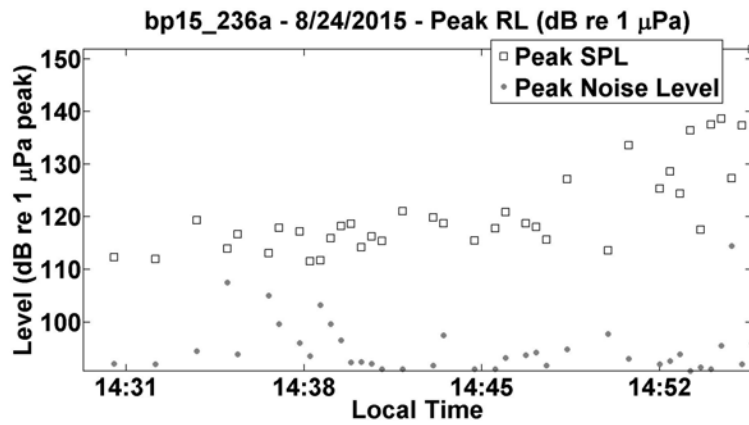
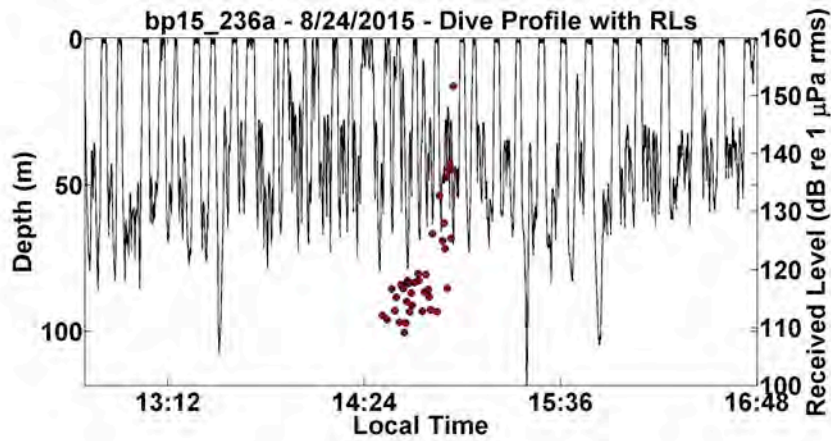
CEE # 2015-05

- DATE and TIME: **22 August 2015 (1716-1746)**
- LOCATION (Source at start of CEE): **West of Catalina (33.3192; -118.9672)**
- FOCAL SPECIES: **BLUE WHALE**
- INDIVIDUAL ID(s): **bw15_234a**
- CEE TYPE (DURATION): **SILENT CONTROL (30:00)**
- SUMMARY: Single blue whale tagged with at least ten blue and fin whales dispersed across in the general area (within 10 nm). Navy ship unavailable to coordinate with SOCAL-BRS so a complete silent control sequence with full focal follow was conducted. Full prey mapping sequences were conducted before and following the silent control. NOTE: unfortunately the DTAG deployed on this whale had a transmitter failure and was not recovered.

CEE # 2015-06

- DATE and TIME: **24 August 2015 (1427-1457)**
- LOCATION (Source at start of CEE): **W of Catalina Island (33.4065; -118.7814)**
- FOCAL SPECIES: **FIN WHALE**
- INDIVIDUAL ID(s): **bp15_236a**
- CEE TYPE (DURATION): **SIMULATED MFAS (30:00)**
- SUMMARY: Single fin whale tagged with at least ten blue and fin whales dispersed across in the general area (within 10 nm). Navy ship unavailable to coordinate with SOCAL-BRS so a complete simulated MFAS sequence with full focal follow was conducted. Full prey mapping sequences were conducted before and following the CEE.

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CEE Summary and Assessment

Given the limited number of tag deployments and successful CEEs in which tags were recovered, SOCAL-15 was quite limited in terms of accomplishments than

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other field seasons. Focal species were located and individuals of three of four (not beaked whales) were tagged, but overall success in locating and tagging individuals was down, in part based on atypical oceanographic conditions associated with the strong El Nino. Field coordination with three different real Navy ships did occur with two successful CEEs, but various other challenges (e.g., lost tags, equipment failures) limited these results.

Significant progress was made in some areas during SOCAL-15. These included complete CEE sequences using MFAS and controls on priority species (blue and fin whales), most of which included prey mapping measurements, and a significant increase in the number of control (no noise) sequences with blue whales. Adaptation of the dispersed mode of operations was applied in which one RHIB was based from San Clemente Island with one or two additional RHIBs based either from mainland or island ports or from the *Truth* depending on circumstances. This modification enabled more tagging options and a more adaptive spread of field effort, which is expected to be integrated more into subsequent efforts. Based on initial assessment of the results, blue and fin whales in SOCAL-15 appeared to respond to sound exposure in a manner consistent with earlier experiments suggesting short-term responses in some but not all conditions with a lack of evident changes in behavior during control (no noise) sequences.

As described above and implemented in SOCAL-14 as in previous field seasons, very specific protocols were in place regarding MFAS transmissions. No CEE sequences were prematurely terminated as a result of specific observed negative reactions, or for animals entered the specified 200m exclusion zone, apparently ignoring ongoing full-power transmissions of the simulated sonar source.

9. OVERALL ASSESSMENT: ACCOMPLISHMENTS VS. OBJECTIVES

The following is an assessment of the specified objectives for SOCAL-15 relative to actual accomplishments. Some but not all objectives were achieved.

- (1) ***Obtain baseline behavioral data*** to support CEE interpretation and conducting CEEs (both realistic sources and scaled sources)

Objective partially achieved. Eighteen tags were deployed on 17 individual animals of three different focal marine mammal species (fin whales, fin whales, and Risso's dolphins), although few beaked whales were seen or heard and no tags were successfully deployed. Over 35h of baseline data (before MFAS transmissions and during control sequences) were collected for fin and blue whales and a small amount on Risso's dolphins. Newly developed medium-duration dart-

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attached archival tags enabling detailed movement and dive data for periods of several weeks were integrated into the SOCAL-BRS approach in 2015, expanding our ability to monitor certain aspects of baseline behavior for much longer periods before and after CEEs.

- (2) ***Conduct controlled exposure experiments (CEEs) with both realistic sources and scaled sources (when realistic ones not available).***

Objective partially achieved. SOCAL-15 was able to coordinate operations with three different real Navy MFAS ship operations, conducting real MFAS CEEs on two occasions. Two simulated MFAS CEEs were conducted when real MFA sources were unavailable as well as two complete control sequences. Furthermore, active acoustic mapping of prey fields as a key contextual variable was conducted for all but one of the baleen whale CEEs. These results were, however, limited for three CEEs by the loss of tags due to transmitter malfunctions.

- (3) ***Test optimal configuration and areas for subsequent studies involving realistic/actual military sources in contrasting modes***

Objective fully achieved. Multiple relatively similar configurations of research vessels, field personnel, and coordination with Navy vessels were used during SOCAL-15. These were largely similar to previous configurations but included different approaches to towed PAM capabilities and also included the use of three RHIBs. These configurations demonstrated the efficacy of a dispersed and adaptable field team.

10. SOCAL-15 TRANSPARENCY AND PUBLIC IMPACT

The SOCAL-BRS project remains committed to openness and transparency of the project and to the timely and effective transmission of results. The increasing body of scientific data generated by SOCAL-BRS (presently twelve peer-reviewed publications have resulted from this project with an additional eight either in press, in review, or in final preparation) is contributing to a greater understanding of biologically important areas in southern California, as well as how marine mammals dive, communicate, and may respond behaviorally to different sounds. Researchers from the SOCAL-BRS team have continued to collaborate with scientists and statisticians working on other BRS projects around the world in terms of data analysis, integration, and communication of results to the scientific, public, and regulatory communities.

Additionally, SOCAL-BRS work has been presented and discussed with various scientific, educational, government, and conservation organizations around the

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world. There were numerous open discussions in at least seven public lectures and webinars, as well as eleven scientific presentations during professional meetings in 2015. There were also many exchanges of questions and responses through the project website www.socal-brs.org and from-the-field blog; and other interactions both public and personal with conservation groups, media, and other scientific projects and disciplines. These interactions increase public awareness of advances in the science of noise and marine mammals and also increase appreciation of important biological areas in the southern California Bight. This is a process that will continue throughout the SOCAL-BRS project.

11. CONCLUSIONS AND NEXT STEPS

Overarching conclusions from SOCAL-15

- * As observed in previous field efforts, coordination of operational Navy sonar training with field tagging efforts can be accomplished, but operational and weather conditions can present challenges and limit achievements.
- * SOCAL-BRS had a perfect record of recovering deployed archival tags for over 150 tag deployments prior to SOCAL-15 during which two tags with CEE data on them were lost. Some tag loss is to be expected over many deployments, but modifications to tag equipment and deployment strategies are being considered and developed for 2016.
- * Ongoing analyses and the practical challenges experienced in coordinating with operational Navy MFAS sources, CEEs with simulated sonar retain some utility, particularly for poorly understood species; maintaining an adaptive approach with possible simulated MFAS CEEs when real Navy sources are unavailable remains important.
- * CEE protocols and safety measures again worked well, including in two occasions with real Navy MFAS sources. Useful behavioral response data were obtained and included some apparent responses in certain conditions, but in no cases were animals harmed or made to respond in extreme ways outside those anticipated and planned for within the protocols.

SOCAL-BRS next steps

Based in part on limited success in SOCAL-15, and with an adaptation of effort to emphasize RHIB-only periods with smaller teams able to more rapidly adapt to changing Navy ship schedules, a final field campaigns (SOCAL-16) will occur, prioritizing real Navy MFAS sources as possible. Efforts on multiple fronts have been undertaken to increase the availability of Navy ships to better participate in 2016 efforts though the success of this is not yet clear. Future SOCAL-BRS

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efforts will include an adaptive mix of field configurations and research teams with an emphasis on small teams (RHIBs-only); three tagging RHIBs will be used in as many field efforts as possible. Both towed PAM and prey mapping applications will be used in RHIB-only configurations, given demonstrated successes from SOCAL-15.