Biological and Behavioral Response Studies of Marine Mammals in Southern California, 2010 ("SOCAL-10")

PROJECT REPORT

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1. EXECUTIVE SUMMARY

SOCAL-10 was a scientific research project conducted in Aug-Sept 2010 in the Southern California Bight. The overall objective was to provide a better understanding of marine mammal behavior, while providing direct scientific data for the Navy and regulatory agencies to estimate risk and minimize adverse effects of human sounds, particularly military sonar. SOCAL-10 extended previous studies in the Bahamas (2007-08) and Mediterranean Sea (2009) of whether and how marine mammals change their behavior when they hear different sounds; each effort integrated behavioral response studies (BRS) with ongoing research on diving, foraging, and social behavior. SOCAL-10 was the first in a five-year dedicated effort to study a variety of marine mammals in this area.

Like previous behavioral response studies (BRS) using controlled (sound) exposure experiment (CEE) methods, SOCAL-10 involved an interdisciplinary collaboration of experts in marine mammal biology, behavior, and communication, as well as underwater acousticians and specialized field researchers[1]. During a preliminary scouting phase and two research legs on different research vessels, SOCAL-10 observed, photographed, and/or tracked in detail, individuals of 21 different marine mammal species. Sixty-three tags (of six different varieties) were successfully secured on 44 individual animals of at least eight different marine mammal species, including several for which little or no comparable tag data previously existed.

Researchers also conducted 28 controlled sound exposure experiments in which animals were monitored with acoustic and movement sensors (attached to animals with suction cups), remote listening devices and specialized observers with reticle binoculars. Sounds simulating military sonar (though several orders of magnitude less intense) and control stimuli were then played to the animals under specific protocols and protective measures (to ensure animals were not harmed) and changes in behavior were measured as a function of sound exposure. Preliminary results based primarily on clearly observable behavior in the field and from initial data assessment indicate variable responses, depending on species, type of sound, and behavioral state during the experiments. Some observations in certain conditions suggest avoidance responses, while in other cases subjects seemed to not respond, at least overtly.

Additional analysis and interpretation is underway of the ~400 hours of tag data, as well as thousands of marine mammal observations, photographs, tissue samples, and acoustic measurements. SOCAL-10 was 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).

[1] For additional information see: http://www.sea-inc.net/SOCAL10/

2. PROJECT OBJECTIVES

The five-year scientific research effort ("SOCAL BRS") of which SOCAL-10 was the first year has the following overarching objective:

> *"The overall SOCAL BRS objective is to provide a scientific basis for estimating risk and minimizing effects of active sonar for the U.S. Navy and regulatory agencies"*

For each field season of SOCAL BRS, the research team has and will develop a number of specific research objectives, which may change based on progress in previous seasons, developments in technology, available resources, and other developments. For SOCAL-10, the following primary and specific objectives were identified:

***SOCAL-10 Primary Objectives*:**

(1) Tag a variety of focal species (primary and secondary) and obtain baseline behavioral data;

(2) Conduct controlled (sound) exposure experiments (CEEs) on focal species using modifications of exposure methodology from previous BRS experiments for odontocetes, adapt and apply protocols for mysticetes, and develop new "tagless" playback protocols where focal animal(s) are not carrying acoustic tags;

(3) Determine optimal SOCAL BRS configuration for subsequent scaled playback configuration (*i.e.*, using speakers to approximate real sources) and use of realistic/actual military sound sources.

***SOCAL-10 Secondary Objective*:**

(1) Obtain basic distribution, behavior, and foraging ecology data for focal marine mammal species and relevant oceanographic data (as possible, given differences in mother vessel capabilities) to support range monitoring and habitat models

3. METHODOLOGY AND FOCAL SPECIES

SOCAL-10 General Methodology

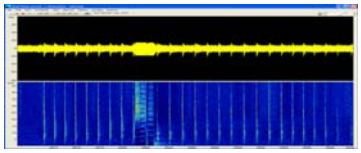
The overall research methods used in the SOCAL-10 projects included standard visual sampling methodologies for detecting and tracking marine mammals, typical small boat operations for photo-identification and tagging of research subjects, acoustic monitoring using various sensors, and the use of controlled sound exposures in order to

Controlled Exposure Experiments ("CEEs") are studies in which the behavior of test subjects are measured before, during, and after controlled sound exposures. Behavioral patterns can be statistically compared for different sounds to identify responses.

study the onset of behavioral responses. SOCAL-10 included highly experienced scientists and engineers from the research organizations listed above, as well as state-of-the-art tools and technologies to tag and track marine mammals and carefully and safely conduct controlled exposure experiments. These assets were organized into specialized interdisciplinary teams, each serving specific, inter-related functions.

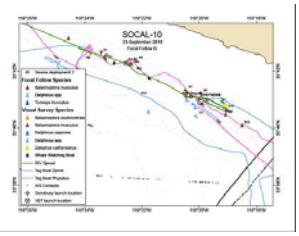
Visual observers, experienced in sighting marine mammals several miles away with specialized binoculars, searched for animals and monitored subjects before, during, and after CEEs.

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.



Passive acoustic observers used different listening systems (depending on the operational location and focal species) from the U.S. Navy SCORE range as well as those deployed from SOCAL-10 vessels to detect vocalizing whales and monitor sound exposures and animal responses during CEEs.

Tagging teams carefully approached and deployed acoustic monitoring tags with non-invasive suction cups from small rigid-hull inflatable boats (RHIBs). The RHIB teams also provided visual monitoring of focal groups during baseline dives and CEEs and recorded behavioral observations.



Geographical Information Systems (GIS) engineers integrated a variety of data streams (including vessel position, visual sightings, and geographic/oceanographic data) for real-time presentation on maps. These data were used for operational awareness and as a time-synchronized archive of all SOCAL-10 vessel movements and other data.

Sound source engineers operated a specialized underwater speaker that was used to play experimental sounds during CEEs. This relatively compact sound projector was a 15-element vertical line array developed specifically for SOCAL-10 to enable the production of various test stimuli at sufficiently loud amplitude.

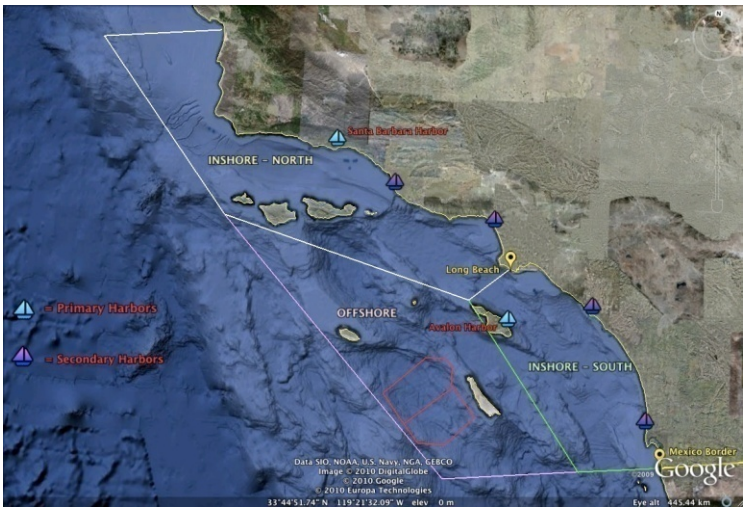
SOCAL-10 Focal Species

This project was conducted under the terms of U.S. National Marine Fisheries Service (NMFS) research permit #14534 (as well as Channel Islands National Marine Sanctuary (CINMS) permit #2010-004 for operations within the boundaries of the CINMS). As specified within permit #14534, a number of "focal" marine mammal species were authorized to be directly studied in the SOCAL BRS project. For each species, a fixed number of "takes" of different types were permitted for different activities, including behavioral observation, close approach for photo ID, attachment of acoustic monitoring tags[2], and sound exposure from vessels, prey-imaging sonars, and CEEs.

For the five-year period of SOCAL BRS the following species were authorized as "focal" species for tagging and CEEs under NMFS permit #14534 (those in **bold** were identified as high priority species in SOCAL-10): **blue whale (*Balaenoptera musculus*)**, **fin whale (*Balaenoptera physalus*)**, gray whale (*Eschrictius robustus*), **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*)**, **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*). As described in greater detail below, during SOCAL-10 most of high-priority focal species were encountered and included in the overall research effort.

We were not authorized to focus on other marine mammal species that may occur in southern California waters, though the permit and accompanying environmental assessment did consider the fact that they could be incidentally exposed to sounds during CEEs, though not within a specified range.

4. OPERATIONAL AREAS & TIMING



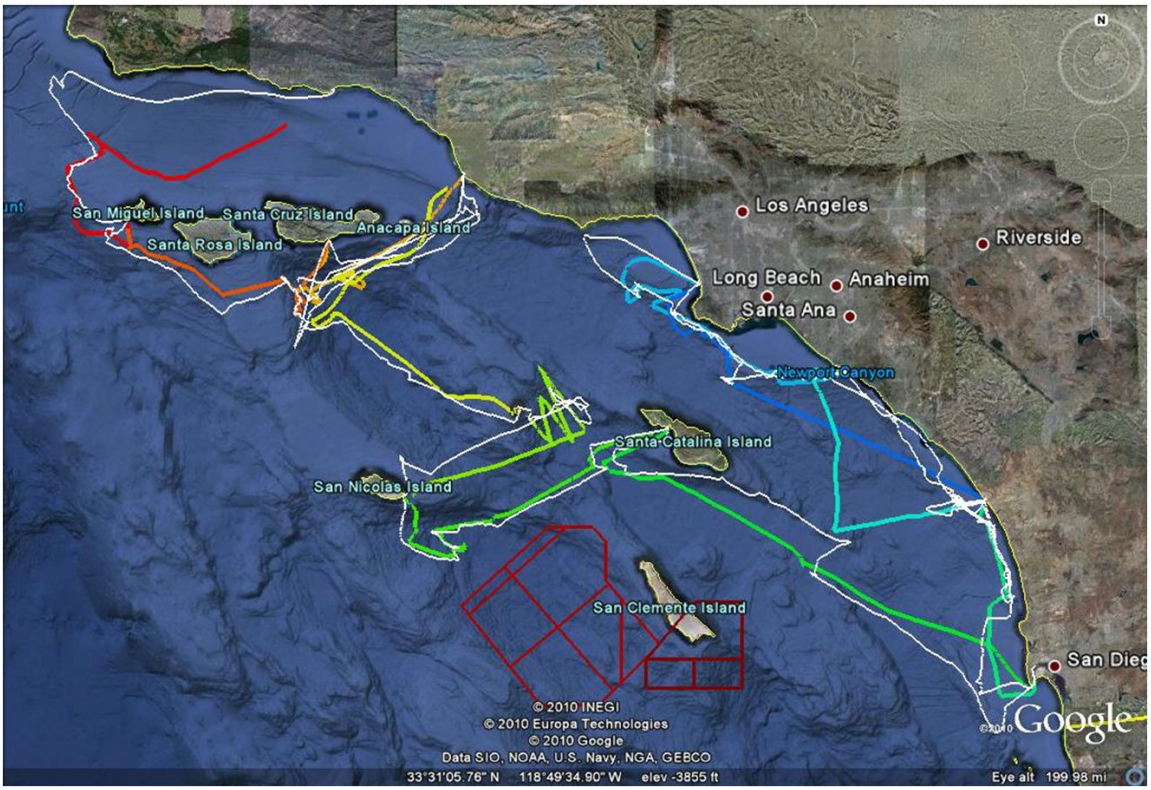
The SOCAL-10 general operational area included both southern and northern "inshore" areas around southern California and an offshore area that includes the U.S. Navy's SCORE range (see figure to right).

SOCAL-10 was conducted in three distinct segments, a "scouting leg" and two experimental phases (hereafter "leg I" and "leg II"). Each of these legs involved slightly different configurations, operational

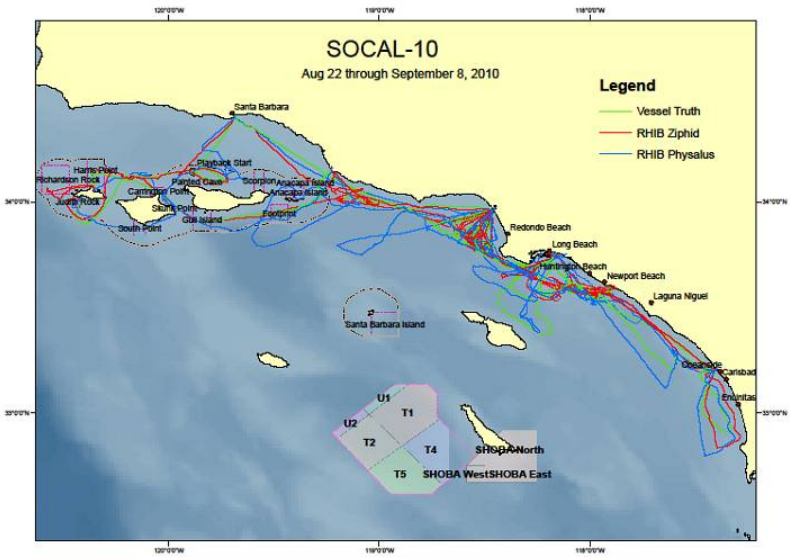
[2] Authorized under a separate NMFS permit (#540-1811).

areas, and somewhat different objectives.

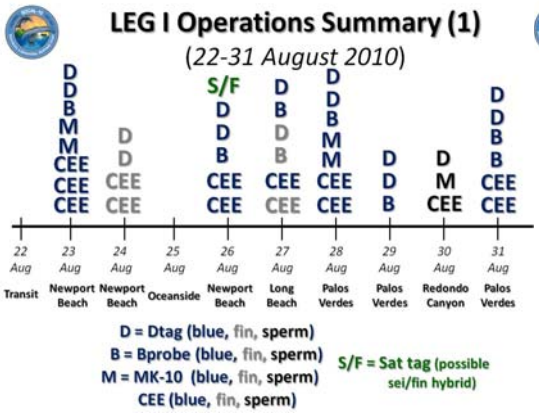
The **SOCAL-10 scouting leg** was conducted from **6 to 18 August 2010**. The *R/V Truth*, which is a ~70-foot dive charter vessel converted for this scientific research project with a specialized marine mammal observation platform and other modifications, was used as a base of operations in conjunction with the tagging RHIBs. As seen in the GIS track in the figure below, during the scouting leg, the *Truth* (tracks shown in different colors by day) and the tagging RHIBs (white tracks) surveyed areas around the northern Channel Islands, offshore areas in the Santa Cruz Basin and around the southern Channel Islands, and a near-shore track from San Diego back up to the Long Beach/L.A. area. The purpose of the scouting leg was to determine the general distribution and abundance of focal species for experimental leg I, to test the overall configuration and train personnel, and to use passive listening sensors to try and identify deep water areas for possible beaked whale studies outside the Navy's SCORE range.

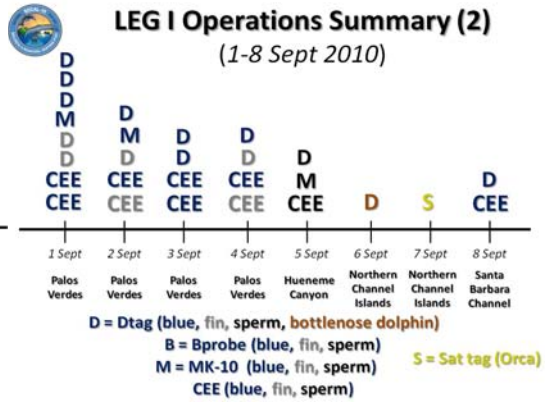


SOCAL-10 experimental leg I was conducted from **22 August to 10 September 2010**, also based from the R/V *Truth*. As seen in map to the right (tracks of both the Truth and two RHIBs are shown – see legend), operations generally occurred in near-shore areas around Palos Verdes and Long Beach as well as (later in this period and to a lesser extent) in the northern Channel Islands.

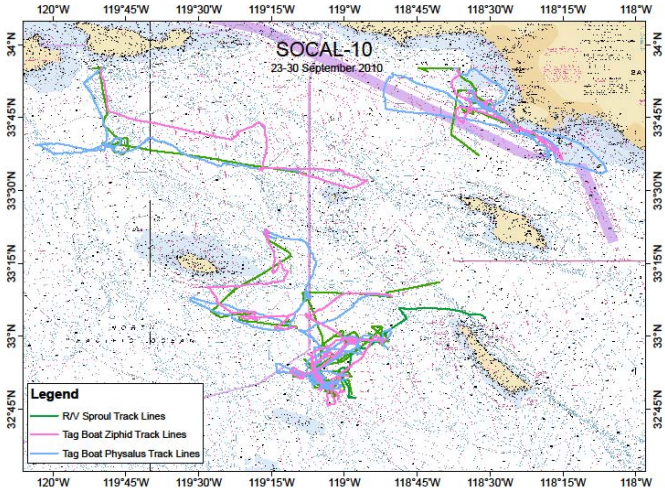


Given the high concentrations and accessibility of blue and fin whales in these areas and the high priority for tagging and CEEs on mysticetes, most of the focus of this leg was on these species. With this and the lack of SCORE range access along with favorable weather offshore, the *Truth* did not operate in the vicinity of San Clemente Island during the first leg. A summary timeline of tag deployments and CEEs by species for the first leg is given below (in two parts); a more detailed summary of tag attachments and CEEs is given in greater detail later in this report.

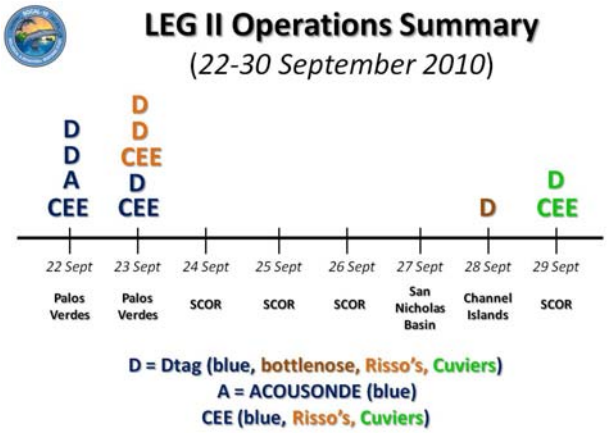




SOCAL-10 experimental leg II was conducted from **21-30 September 2010** aboard the R/V *Sproul*, which is a 125-foot oceanographic research vessel from Scripps Institution of Oceanography. This leg focused initially in the area around the Palos Verdes Peninsula where leg I operations were largely concentrated but then primarily around the SCORE range off San Clemente Island and in areas of the Santa Cruz Basin (see figure to right – note legend).



Given the ability for the larger *R/V Sproul* to load and carry the RHIBs and thus not require a daily port base of operations, this leg was more focused on offshore areas and on more difficult to detect and tag species, primarily beaked whales but also Risso's dolphins. Very favorable weather coupled with access to the SCORE range at the end of this leg resulted in the first ever CEE on a Cuvier's beaked whale during leg II. A summary timeline for leg II was presented and is given below. The much greater relative difficulty of tagging/CEE for the species targeted during the second leg should be kept in mind when comparing these accomplishments to those of leg I.



5. VISUAL SURVEY RESULTS

Trained and experienced marine mammal visual observers were used both on the primary research vessel (*R/Vs Truth* or *Sproul*) and on the small RHIBs during all phases of SOCAL-10. The use of visual observers from the RHIBs as a primary, and in fact initial lead, in locating and following potential tagging subjects was a significant evolution from previous, related BRS efforts in the Bahamas and Mediterranean Sea. The use of two RHIBs capable of operating independently from the source vessel and conducting visual surveys and focal follows that could be integrated into the visual survey results from the primary research vessel was an important development in SOCAL-10.

Visual observers were on duty during essentially all daylight hours when weather and sea conditions permitted. On the primary research vessel, a team of 2-3 visual observers were based on an elevated (6-7m) observation platform with a wide field of view. These observers used handheld reticle binoculars (7X50 Fujinon and 15X80 Steiner) and an angle board to determine range and bearing of sightings for entry into the specialized geospatial software system (WILD). Observers from the RHIBs used primarily naked eye observations. For both platforms, visual observation data were collected in three different operational modes:

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

Focal Follow Mode – a dedicated tracking of specific individual(s)

Mitigation Mode – a dedicated survey of an area for a period after CEEs

Within each operational leg and across teams and observational modes, the following are the summarized visual survey results for SOCAL-10:

Scouting leg:

- A total of 16 marine mammal species were observed from the R/V Truth with 269 sightings and an estimated 5,870 individuals.

- A total of 15 mammal species were observed from the RHIBS with 251 sightings and estimated 3,337 individuals.

Experimental legs I and II:

- A total of 21 marine mammal species were observed from the *R/V Truth* with 479 survey sightings and 47 individual/group focal follows.

- A total of 23 mammal species were observed from the RHIBs with 595 sightings and an estimated 9,629 individuals

6. SUMMARY OF TAG DEPLOYMENTS

Following visual detection of appropriate focal species and group configuration, highly experienced field personnel in the small RHIBs approached subjects to attempt tag attachments. A variety of different kinds of acoustic and movement tags were used in SOCAL-10, each with somewhat different capabilities and thus overall objectives. These included:

DTAGs – designed and supplied by WHOI collaborators[3], these tags are attached with suction cups for up to tens of hours, recording continuous broadband received sound (variable from a few hundred Hz up to 96 kHz) as well as depth and 3-D acceleration.

Bprobes – designed by Greeneridge Sciences, Inc, these tags also use suction-cup attachment for up to tens of hours and record continuous broadband received sound (variable from ~50 Hz up to 8 kHz) as well as depth and 3-D acceleration.

Mk-10s[4] – designed by Wildlife computers, these tags are also attached with suction cups for temporary attachments of up to tens of hours; they measure dive characteristics and GPS positions when the animal is at the surface.

ACOUSONDEs[5] – these are the next generation of the Bprobes from Greeneridge Sciences, Inc with similar functions but greater data storage and sampling bandwidth; we deployed one of these in SOCAL-10 which was the first on-animal deployment of this new sensor.

Various Time-Depth Recorders and Satellite positional tags

[3] 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.

[4] http://www.wildlifecomputers.com/Products.aspx?ID=34

[5] http://www.acousonde.com/

Depending on the focal species, environmental conditions, timing, and other practical considerations, different combinations of these tags were used in different circumstances. In some cases where possible for large whale species, we used dual deployments to obtain a more robust set of measurements of diving, acoustics, and geographic position. SOCAL-10 managed to tag a wide variety of species and a large number of individuals, with blue whales comprising the greatest overall numbers. As described above, leg I was more concentrated in near-shore areas and large whales whereas leg II had a more offshore focus with favorable conditions for deep-diving species such as Risso's dolphins and beaked whales. During leg I, a satellite tag was attached to one individual identified in the field as a sei whale that may be either a sei whale, a sei/fin whale hybrid, or a fin whale (pending ongoing genetic analysis). Below are the successful attachments for the scouting/leg I and leg II, by tag type and species.

Scouting and LEG I Tag Summary:		56 tags of 5 types on 37 individuals of 6 or 7 species
25 Days	Blue Whales:	25 total individuals (21 Dtags; 9 Bprobes; 8 MK-10s)
	Fin whales:	7 total individuals (7 Dtags; 1 Bprobe)
	Sperm whale:	One individual (2 Dtags; 2 MK-10)
	Baird's Beaked whale:	One individual (satellite tag)
	Possible sei/fin hybrid:	One individual (satellite tag)
	Bottlenose dolphin:	One individual (TDR)
	Killer whale:	One individual (satellite tag)

LEG II Tag Summary:		7 tags of 2 types on 7 individuals of 4 species
10 Days	Blue Whales:	3 total individuals (2 Dtags; 1 ACOUSONDE)
	Rissos dolphins:	2 total individuals (2 Dtags)
	Bottlenose dolphin:	One individual (Dtag)
	Cuvier's Beaked Whale	One individual (Dtag)

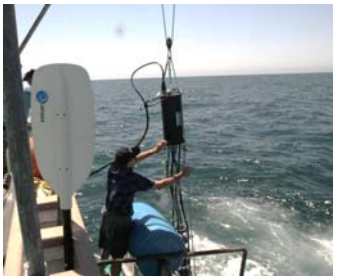
SOCAL-10 succeeded in attaching 63 tags of six different types on 44 individuals of at least eight different marine mammal species. For the suction cup acoustic/position tags used in SOCAL-10 (not including the satellite tags), this resulted in ~400 hours of tag data across these individuals, the majority (225 h) coming from the Dtags.

7. CONTROLLED EXPOSURE EXPERIMENTS (CEEs)

General Methodology and Sound types

CEEs were conducted using similar methods and sound types to previous, related

studies in the Bahamas in 2007-08[6]; these methods are based on established methods to assess behavioral responses using a before, during, after paradigm. First, all possible means of monitoring animals (visually, 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 mid-frequency military sonar and noise control signals 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. Detailed analysis of movement and vocal behavior in each of these three phases is ongoing to assess any changes in behavior as a function of sound exposure during CEEs. The baseline period served as the primary control comparison against responses in the exposure phase, although in certain conditions when animals were tagged but we were unable to proceed with a CEE because protocol conditions were not met (*e.g.*, presence of neonate animals that would be exposed), a full control sequence was conducted with a baseline period, a "mock" exposure (source deployed but not transmitting), and a "post-exposure" sequence.



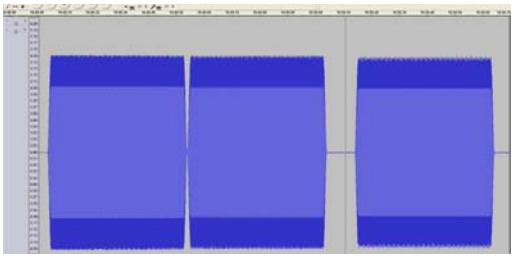
The SOCAL-10 sound source was custom-built for this project, with the primary goal of reducing the size of both the transducer and the dry-side electronics from previous efforts (in the Bahamas and Mediterranean Sea). The source could transmit mid-frequency signals at relatively high output levels while running off the ship's AC power supply. It consisted of a 15-element vertical line-array of individual ceramic disk-shaped transducers powered individually and controlled to form a single output beam. Overall, the sound source performed exceptionally well and met the stated objectives in a very compact package that was easily deployed and retrieved by hand. Its small dry-side footprint enabled it to be operated from the relatively small *R/V Truth* (and very easily from the larger *R/V Sproul*). Ramp-up sequences were as planned and the maximum output levels were as specified and expected from calibraiton trials. However, problems were encountered in the temporal spacing of transmission sequences due to software control errors. This resulted in some deviation from the planned 25s duty cycle, but did not affect the total transmission period (30 min. maximum).

Two sound types were transmitted during CEEs in SOCAL-10. Because a primary objective was to provide information relevant to the potential effects of military sonar on marine mammals, a simulated mid-frequency active (MFA) sonar signal was used.

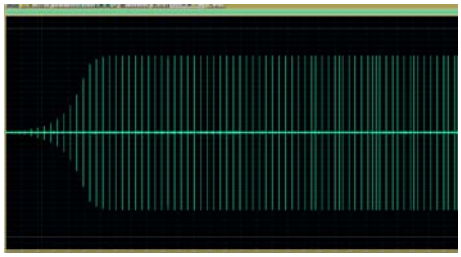
[6] Beaked Whales Respond to Simulated and Actual Navy Sonar. (in press). Tyack, P.L., W.M.X. Zimmer, D. Moretti, B.L. Southall, D.E. Claridge, J.W. Durban, C.W. Clark, A. D'Amico, N. DiMarzio, S. Jarvis, E. McCarthy, R. Morrissey, J. Ward, I.L. Boyd. PlosOne.

This signal was designed to be similar to the general category of transmit waveforms used in SQS-53C tactical sonars by the U.S. Navy and other nations. However, it is best described as a simulated MFA signal because, while features of the waveform were specifically designed to mimic the signals used in these systems, the maximum output levels were much lower (~25 dB) than real sonars, as well as other important differences For instance, SOCAL-10 sources were stationary whereas Navy ships are mobile, sometimes at relatively high speeds, and SOCAL-10 transmissions lasted a maximum of 30 min total whereas Navy sources may operate for considerably longer and cover much larger areas.

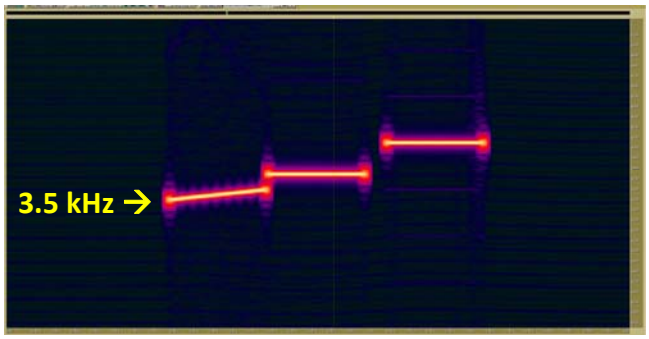
The MFS signal had a 0.5s linear frequency modulated upsweep from 3.5 to 3.6 kHz, a 0.5s constant frequency tone at 3.7 kHz, a 0.1s silent interval, and a 0.3s constant frequency tone at 3.9 kHz. Thus the total duration of the MFA signal was 1.4s and sounds were nominally transmitted once every 25s (to mimic the output characteristics typical of many 53C systems) beginning at a broadband source level of 160 dB re: 1µPa (RMS) up to a maximum transmitted source level of 210 dB re: 1µPa. This resulted in a maximum of 72 total signals, just over one minute of total output energy per CEE sequence. Depictions of the MFA signal in the time and frequency domains, as well as a full transmission sequence recorded from a monitoring hydrophone are shown below.



MFA time domain representation



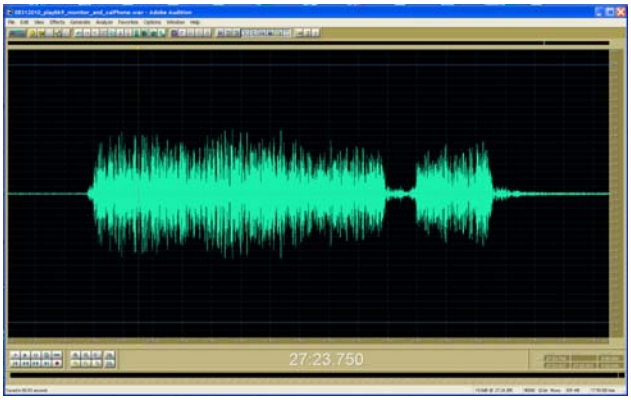
MFA transmission sequence



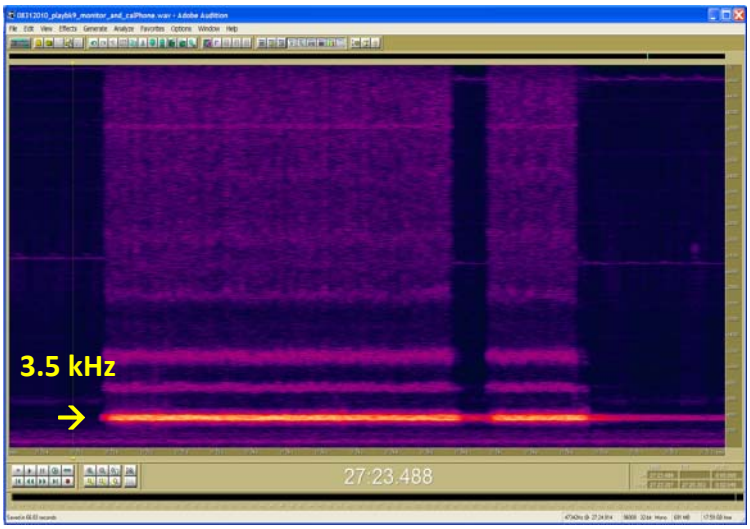
MFA frequency domain representation

The pseudo-random noise (PRN) stimulus was made up of a 1 sec signal of noise in the 3.5 to 3.9 kHz frequency band, followed by a 0.1 sec silent interval, followed by a 0.3 sec

signal of noise in the 3.5 to 3.9 kHz frequency band. Like the MFA stimulus, the PRN signal lasted for an total duration of 1.4 sec and was repeated every 25 sec, ramping up 3 dB per transmission from 160 dB re: 1µPa to the maximum output source level (which was 206 dB re: 1µPa for this sound type). The total maximum transmission time was 30 min (*i.e.*, 72 total signals maximum or just over one minute of total output energy per CEE sequence). Waveform and frequency domain signals are shown below.



PRN time domain (waveform) representation



PRN frequency domain representation

Specific CEE Protocols and Shut-Down Criteria

The specific protocols for conducting CEEs in SOCAL-10 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 CEEs:

- Tags were attached for a sufficient duration to reduce attachment disturbance

effects and obtain a reasonable amount of baseline behavioral data (both on tags and using visual observations). For mysticetes this was a minimum of 45 min and ideally two hours and for odontocetes (to include 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-10 vessels) are likely to allow for successful completion of CEE and interpretation of results, as well as post-exposure monitoring;
- Determine that the SOCAL-10 sound source is not within 1nm of any landmass or within 3nm from land within the Channel Islands National Marine Sanctuary; and
- Ensure that, if a SOCAL-10 CEE had occurred earlier in the day, focal animals were at least 10 nm from the site of the previous sound transmissions.

Provided that these conditions were met, as agreed upon by the chief scientist and co-investigators in the field, SOCAL-10 researchers would then proceed with CEEs according to the following procedures:

- Position source vessel ~1000m from the focal group or animal, taking into account group movement/distribution, to extent possible;
- Reduce engine propulsion noise and speed, as much as possible;
- Deploy source to specified depth (~25m for most species; 50m for beaked whales);
- Determine no marine mammals within 200m of source vessel;
- Initiate sound transmissions at a source level of 160 dB re: 1µPa, 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; and
- One exposure type was used per focal individual/group, with sufficient pre-exposure baseline and as much post-exposure “recovery” as possible.

During CEEs the following safety shut-down protocols were used, any of which resulted in the immediate termination of active sound exposures:

- *Any marine mammal inside 200m shut-down zone* around 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 behaviors[7]:

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 include dependent calves that are not neonates (no fetal folds for non-ESA 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.

- For beaked whale CEEs on the U.S. Navy SCORE range in SOCAL-10, we used the same criterion as in BRS-07/08 in the Bahamas. Under this protocol animals were only exposed during their deep foraging dives and exposures were terminated when the focal group ceased producing echolocation clicks[8].

Following CEEs, the following post-exposure monitoring was conducted after sound transmission:

- Either the source boat and/or RHIB visual teams maintain visual (and passive acoustic monitoring (PAM), if applicable/possible) monitoring 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, typically for a period of 10 min immediately following the CEE, followed by a five min. pause, and another 10 min "mitigation" monitoring period.

Summary of CEEs Conducted

During the two experimental legs of SOCAL-10, CEEs were successfully completed with 28 tagged (with acoustic suction cup tags – Dtags and/or Bprobes) individuals of five marine mammal species (see below).

Blue Whales: 19	Fin Whales: 5	Sperm Whale: 2	Risso's Dolphin: 1	Cuvier's beaked whale: 1

[7] None of these behaviors were observed in any CEE sequence

[8] Note that in subsequent years, this protocol will likely include options for continuing or initiating exposures during/though surfacing sequences

Twenty complete CEE sequences were conducted in order to complete CEEs on these 28 individuals, as well as three additional cases where for various reasons (*e.g.*, presence of a neonate animal in the transmission area) conditions were not suitable for sound transmissions and a "mock" exposure was conducted where the source was deployed but not engaged. The total number of tagged animals involved in CEEs exceeds the total number of CEE sequences because eleven of the 20 CEE sequences involved multiple animals, several of which involved animals of different species (blue and fin whales).

A chronological list of the 20 CEE sequences showing general operating area, species type and number, the sound exposure type and duration, and the behavioral state of the animals during the CEE is given on the following page. As can be seen in this table, on multiple occasions sound transmissions were terminated during CEEs prior to the 30 min. maximum transmission. These were due to: marine mammals entering the 200m "shut-down" zone around the sound source (sea lions: sequences #2010_02 and 2010_12; common dolphins: sequence #2010_17) or due to the sperm whale surfacing at the end of a foraging dive (#2010_15).

CEE Sequence	Date	Location	Species	CEE stimulus (duration)	Behavioral State
#2010_01	23 Aug 10	West of Newport Beach Harbor	**2 blue whales**	**MFA** (30:00)	Surface feeding/social
#2010_02	23 Aug 10	West of Newport Beach Harbor	**1 blue whale**	**MFA** (18:00)	Deep feeding/travel
#2010_03	24 Aug 10	West of Newport Beach Harbor	**2 fin whales**	**MFA** (30:00)	Surface feeding/social
#2010_04	26 Aug 10	West of Newport Beach Harbor	**2 blue whales**	**MFA** (30:00)	Surface feeding/social
#2010_05	27 Aug 10	South of Long Beach Harbor	**1 blue whale 1 fin whale**	**MFA** (30:00)	Surface feeding/social
#2010_06	28 Aug 10	South of Palos Verdes peninsula	**2 blue whales**	**MFA** (30:00)	Surface feeding/social
#2010_07	29 Aug 10	South of Palos Verdes peninsula	**2 blue whales**	**CONTROL** (30:00)	Surface feeding/social
#2010_08	30 Aug 10	Redondo Canyon	**1 sperm whale**	**MFA** (30:00)	Deep feeding/travel
#2010_09	31 Aug 10	West of Palos Verdes peninsula	**2 blue whales**	**PRN** (30:00)	Deep feeding/travel
#2010_10	1 Sep 10	West of Palos Verdes peninsula	**2 blue whales**	**PRN** (30:00)	Deep feeding/travel
#2010_11	2 Sep 10	West of Palos Verdes peninsula	**1 blue whale; 1 fin whale**	**PRN** (30:00)	Surface feeding/social
#2010_12	3 Sep 10	West of Palos Verdes peninsula	**2 blue whales**	**MFA** (25:00)	Deep feeding/travel
#2010_13	4 Sep 10	West of Palos Verdes peninsula	**1 blue whale; 1 fin whale**	**PRN** (30:00)	Surface feeding/social
#2010_14	5 Sep 10	Hueneme Canyon	**1 sperm whale**	**CONTROL** (30:00)	Deep feeding/travel
#2010_15	5 Sep 10	Hueneme Canyon	**1 sperm whale**	**PRN** (24:00)	Deep feeding/travel
#2010_16	8 Sep 10	Northern Channel Islands	**1 blue whale**	**PRN** (30:00)	Deep feeding/travel
#2010_17	22 Sep 10	West of Palos Verdes peninsula	**1 blue whale**	**MFA** (19:00)	Deep feeding/travel
#2010_18	23 Sep 10	West of Palos Verdes peninsula	**1 Risso's dolphin**	**MFA** (30:00)	Surface/resting mode
#2010_19	23 Sep 10	South of Palos Verdes peninsula	**1 blue whale**	**PRN** (30:00)	Deep feeding/travel
#2010_20	29 Sep 10	SCORE range west of SCI	**1 Cuvier's beaked whale**	**MFA** (30:00)	Deep feeding/travel

CEE Preliminary Results by species

A summary of the CEEs conducted by species as well as the preliminary observations of behavioral responses in each case is given below. Detailed analysis of movement, diving, vocal, and/or respiratory behaviors in the "baseline", "exposure", and "post-exposure" phases of CEEs are currently being conducted to assess the specific responses to sounds of each type in relation to baseline behavioral conditions. The following observations should be considered preliminary based on clear differences in behavior from visual monitoring and/or initial analysis of the tag data; additional or different subtle responses may be revealed by the more detailed behavioral assessments that are currently ongoing.

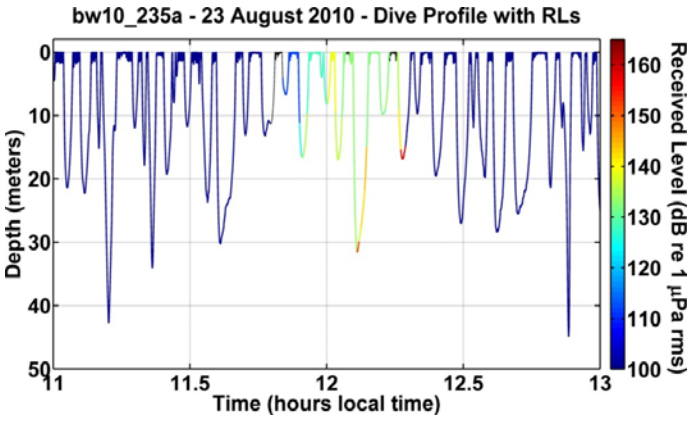
Blue whales

The largest number of CEEs in SOCAL-10 was conducted on blue whales (n=19). Of these, 11 were conducted with the MFA sound type and eight using PRN. In two cases blue whales were tagged but conditions were not acceptable to proceed with sound transmissions so a control ("mock" exposure) sequence was conducted (described above). For each sound type, some exposures were conducted when animals were in a surface feeding (~50m or less) and/or socializing behavioral state and others while animals were in a deep feeding (>50 m) and/or traveling mode (see table below).

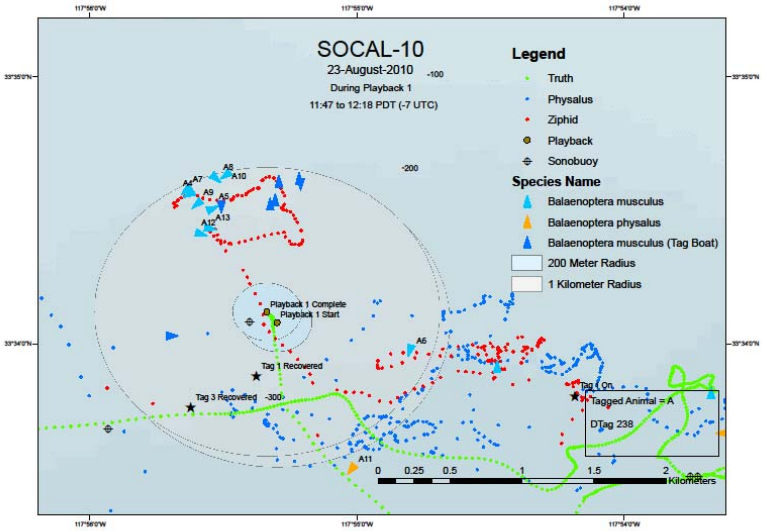
Species	Exposure Type	N	Behavioral State Breakdown
BLUE WHALE	MFA-1	11	Surface/shallow feeding: n = 7 Deep feeding/travel: n = 4
BLUE WHALE	PRN-1	8	Surface/shallow feeding: n = 2 Deep feeding/travel: n = 6
BLUE WHALE	CONTROL	2	Surface/shallow feeding: n = 2 Deep feeding/travel: n = 0
BLUE WHALE	TOTAL	21	TOTAL - ALL SEQUENCES

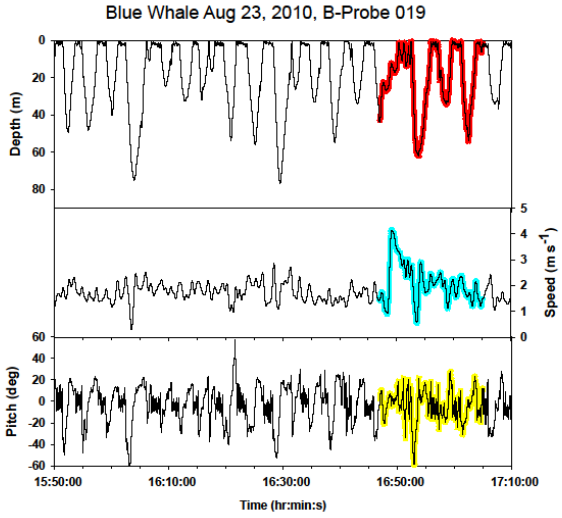
All CEE transmissions were detected on the acoustic tags for all animals, but for blue whales, the received sound levels during CEE sequences were the most variable of the species tested, in large part because so many involved multiple animals. In these cases, one of the RHIBs would remain with each focal while but the main research vessel with

the sound source would focus on one, projecting experimental sounds at a range of ~1000m from that whale; focal animals in this range (and who sometimes moved closer during transmissions) received sound levels from just detectable over the background ambient up to the target received sound level of 160 dB re: 1µPa. The strategy of focusing on one whale while monitoring another with tags and RHIB observations resulted in the second whale sometimes being multiple kilometers further away and receiving lower sound energy; the comparison of responses to the same source at somewhat lower levels but out of visual detection range for the animals will be an interesting and important one.

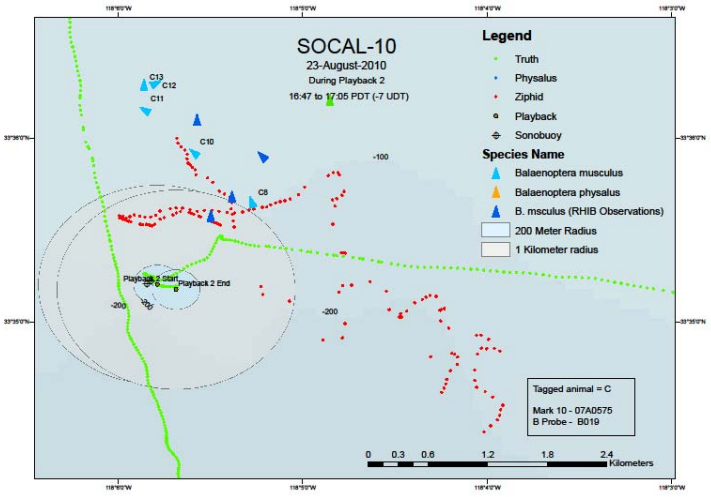


For the majority of CEE transmissions of either sound type, there were few obvious behavioral responses detected either by the visual observers or on initial inspection of the tag data. A dive profile of a blue whale from sequence #2010_01 is shown to the right. The dive profile is illustrated in color indicating the received sound level from about 100-160 dB re: 1µPa RMS with levels increasing initially due to the sound ramp-up and with the highest received levels relatively deeper in the (shallow) dives. The spatial movement of animals was also monitored during the CEE and was visualized using the WILD software. The figure below/left shows a spatial representation of this tagged animal, as well as the second blue whale involved in CEE #2010_01 on 23 Aug. The small blue triangles in the middle-left of the figure show this focal group (A) with sequential numbers indicating each sighting. Throughout the CEE, up to the highest received sound level (absolute RMS value ~160 dB re: 1µPa with signal-to-noise ratio values over 60 dB), both whales continued surface feeding behavior and remained at a range of around 1000m from the sound source.





In contrast, another blue whale (later in the day and >10 nm from the first CEE location) exposed to the same stimulus (MFA) while engaged in a deep feeding/travel state exhibited a different response. In this case (CEE #2010_02), the whale responded almost immediately following the start of sound transmissions (shaded sections of plots to right) when received sounds were just above ambient background levels. As seen in the top plot (highlighted in red), the animal displayed an unusual ascent and surfacing behavior following the start of MFA transmissions. This was accompanied by a rapid acceleration, as seen in the middle plot (highlighted in blue). In looking at the directional movement of the whale, it is clear that this acceleration was away from the sound source. The WILD plot to the left shows the animal (light blue triangles with group C sequential labels) directed away from the sound source just after transmissions begin; this directed avoidance behavior appears to end following the cessation of this CEE (which lasted just 19:00 total due to a sea lion swimming inside the 200m shut-down zone during transmissions).



This kind of temporary avoidance behavior was not evident in any of the nine CEEs involving blue whales engaged in surface feeding or social behaviors, but was observed in three of the ten CEEs for blue whales in deep feeding/travel behavioral modes (one involving MFA; two involving PRN). For the sequences (like #2010_02 described above) where this avoidance response occurred, it did not appear to increase as a function of higher received levels necessarily. Again, these observations are based on visual observations of animals in the field and an initial inspection of the tag data; more detailed analyses of all CEE sequences is ongoing and may reveal some more subtle responses in either behavioral mode. However, as a preliminary assessment, some behavioral avoidance behavior was observed in a few of the SOCAL-10 CEEs involving 19

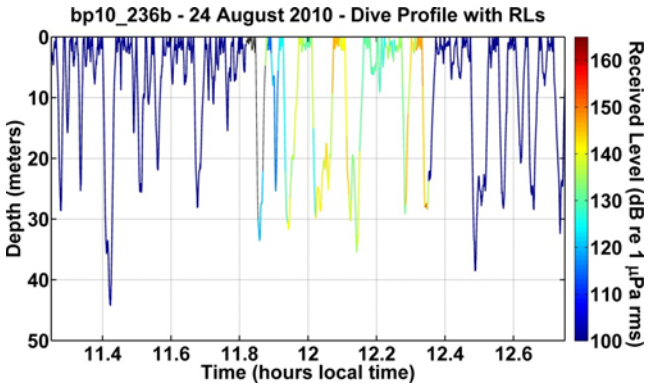
individual blue whales, but these responses seemed to have been driven more by the behavioral state of the animals during exposure than the specific sound exposure type or the received level of sound.

Fin whales

For fin whales, a relatively smaller total number (n=5) were tagged and involved in CEEs than blue whales. Four of these whales were engaged in surface feeding/social behavior while just one was engaged in deep feeding/travel mode during CEEs (note: this whale was engaged in surface feeding behavior at other times during this tag deployment). Several of the fin whale CEEs were conducted in mixed aggregations with blue whales, including three sequences where a blue whale was tagged in addition to the focal fin whale.

Species	Exposure Type	N	Behavioral State Breakdown
FIN WHALE	MFA-1	3	Surface/shallow feeding: n = 2 Deep feeding/travel: n = 1
FIN WHALE	PRN-1	2	Surface/shallow feeding: n = 2 Deep feeding/travel: n = 0
FIN WHALE	CONTROL	0	Surface/shallow feeding: n = 0 Deep feeding/travel: n = 0
FIN WHALE	TOTAL	5	TOTAL - ALL SEQUENCES

The fin whale CEE results were similar to the blue whales engaged in surface feeding/social behavior; no obvious responses were detected by visual observers or are clearly evident in the initial tag analysis. An example dive profile from one of the five fin whales (CEE #2010_03) is given here (right), which is typical of the behavior observed. During this and the other CEEs for fin whales, received sound levels ranged from just above ambient noise up to about the 160 dB re: 1µPa level



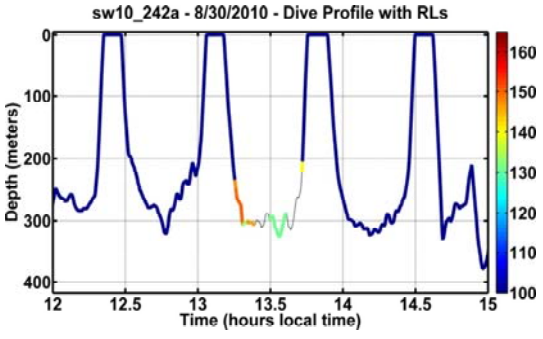
that was the specified maximum value. In none of the five fin whales tested, was avoidance or other behavioral responses readily evident, at least based on preliminary observations.

Sperm whale

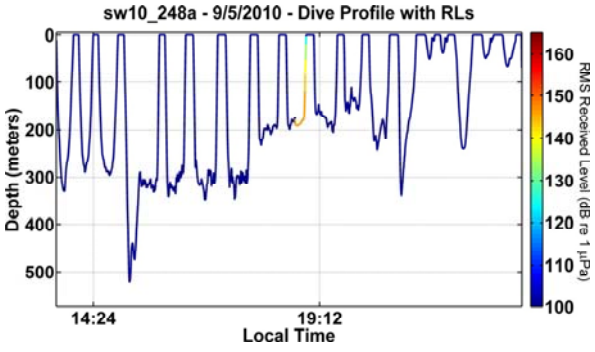
A single sperm whale was involved in SOCAL-10 CEEs. A satellite tag was attached to this adult male during the scouting leg. On two occasions, he was re-tagged with acoustic and dive/GPS sensors for short-term measurements in conjunction with CEEs. Both MFA and PRN were used (CEEs #2010_08 and #2010_15 respectively), each of which was conducted during deep feeding/travel behavioral modes.

Species	Exposure Type	N	Behavioral State Breakdown
SPERM WHALE	MFA-1	1	Surface/shallow feeding: n = 0 Deep feeding/travel: n = 1
SPERM WHALE	PRN-1	1	Surface/shallow feeding: n = 0 Deep feeding/travel: n = 1
SPERM WHALE	CONTROL	0	Surface/shallow feeding: n = 0 Deep feeding/travel: n = 0
SPERM WHALE	TOTAL	2	TOTAL - ALL SEQUENCES

In neither CEE did this individual appear to demonstrate obvious behavioral responses, as seen in the dive profiles below; no clear changes in the production of echolocation clicks were observed in either case.



Sperm whale dive profile during MFA



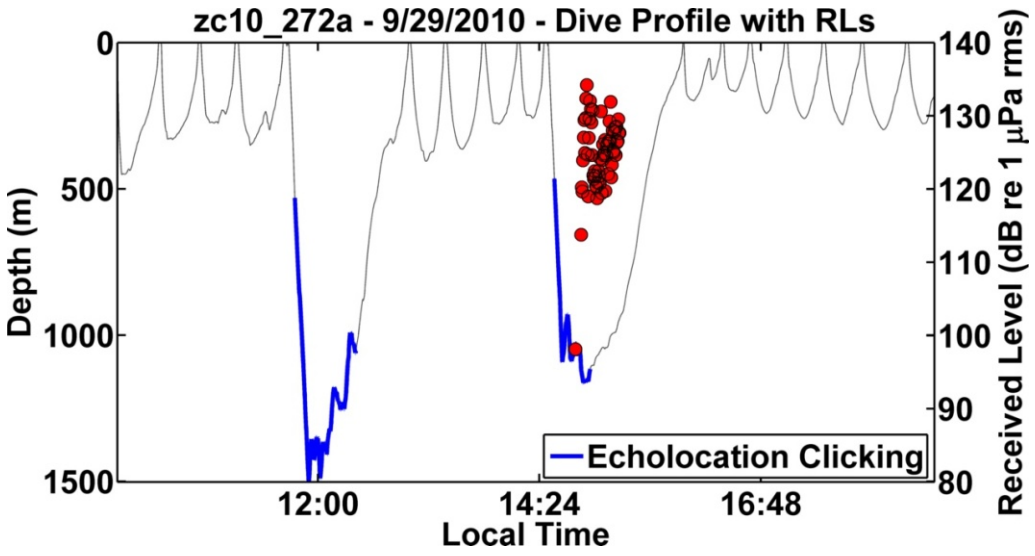
Sperm whale dive profile during PRN

Risso's dolphin

Previous efforts to attach suction cup acoustic tags to Risso's dolphins had been largely unsuccessful and the two successful (though short) attachments and baseline behavioral data for this species were an accomplishment in and of themselves. The second tag remained attached for about two hours, during which time CEE sequence #2010_18 was conducted using MFA sound exposure for the focal tagged animal in a group of approximately 20 individuals. This group was largely in a surface resting/very slow travel state during this period of time and exhibited no obvious response to the sound exposures, which ranged from just above ambient noise to approximately 135 dB re: 1µPa in the tagged individual.

Cuvier's beaked whale

The final tag attachment and CEE (#2010_20) in SOCAL-10 was on an adult male Cuvier's beaked whale. This represented was the first suction cup acoustic tag attachment on this species in the Pacific Ocean and the first-ever CEE conducted on this species, which is the most prevalent species in known marine mammal strandings associated with the use of mid-frequency military sonar systems. This individual was in a group of five individuals that were diving roughly synchronously, with a larger group of as many as 17 beaked whales in the same general area of the SCORE range to the west of San Clemente Island. These groups were being visually monitored during their brief periods at the surface from both the RHIBs and the *R/V Sproul*, and were acoustically monitored both by the SCORE hydrophones and from sonobuoys deployed from the *Sproul*. The focal beaked whale completed one full deep dive sequence and four "shallow" dives before it was exposed to the MFA stimulus on the second deep dive. Diving behavior and sound production (echolocation clicks) were measured from the Dtag attached to this animal, as well as the received sound level from the MFA sound exposure.



Received MFA signals on the whale during this CEE sequence ranged from just above ambient noise to about 135 dB re: 1µPa RMS (signal-to-noise ratios on the order of 40 dB). Several responses seem to have occurred, based on an initial assessment of the tag data, which appear generally similar to the responses of Blainville's beaked whales observed in the Bahamas during BRS-07/08. The animal appears to have terminated its normal prey-searching behavior prematurely and ceased echolocation clicking relatively soon after the onset of sound transmission. Also, while the overall dive duration is relatively similar to the baseline dive, the duration of the ascent is elevated and the slope appears to be slightly shallower than on the baseline dive. Further, the first "shallow" dive following the deep dive with MFA transmissions includes an aborted return to the surface that appears somewhat different from preceding or subsequent "shallow" dives. Finally, the relative heading data from the Dtag during this sound exposure indicates a very directional movement with a sustained and elevated level of fluking behavior. Because the animal was not visually detected again following the MFA CEE it is unclear as to precisely which direction the animal moved, but it seems to have moved in a concerted and directional manner for at least 40 minutes beginning shortly after the onset of MFA sound transmissions. However, the tag was recovered the following day in the same general area of the SCORE range.

With the caveat that these are data for one individual and that more detailed analyses are underway of CEE #2010_20, preliminary observations of this CEE are that the animal seemed to demonstrate similar kinds of changes in diving and vocal behavior consistent with temporary avoidance responses that were observed in two Blainville's beaked whales in the Bahamas (BRS-07/08)[9].

8. OVERALL ASSESSMENT: ACCOMPLISHMENTS VS. OBJECTIVES

The following is a simple assessment of the specified objectives for SOCAL-10 relative to the accomplishments realized during the scouting and two experimental legs. All objectives were achieved, with expectations exceeded in most regards.

1) *Tag a variety of species and obtain baseline behavioral data*

   A total of 63 tags of six different types were on deployed on 44 individuals of at least eight species (pending final genetic results on the possible sei/fin whale hybrid satellite tagged during leg I); nearly 400h of tag data were obtained from the diving and acoustic tags (with weeks of positional data for satellite tagged animals).

[9] Beaked Whales Respond to Simulated and Actual Navy Sonar. (in press). Tyack, P.L., W.M.X. Zimmer, D. Moretti, B.L. Southall, D.E. Claridge, J.W. Durban, C.W. Clark, A. D'Amico, N. DiMarzio, S. Jarvis, E. McCarthy, R. Morrissey, J. Ward, I.L. Boyd. PlosOne.

2) Conduct CEEs using similar methods to previous studies

Twenty CEE sequences (18 involving sound transmissions) were conducted on 28 individuals of five marine mammal species using two different sound types (MFA and PRN). For three of the five species, these were the first-ever known CEEs, and for all five these were the first-ever with simulated mid-frequency military sonar commonly used in operational training exercises.

3) Test optimal configuration for subsequent studies, which may include realistic/actual military sources.

There were successful aspects of both the smaller dive boat (*R/V Truth*) and larger/more conventional research configuration (*R/V Sproul*). The former allowed somewhat greater operational flexibility and was particularly suited to the coastal approach targeting large baleen whales, while the later was better-suited for offshore operations targeting the pelagic, deep-diving odontocetes. SOCAL-10 proved the concept of working with smaller, more agile research platforms and teams, as well as the transition of CEE methods from previous studies to the suite of species off southern California. Additional modifications may include even smaller research platforms and observations in preparation for tracking animals around real training exercises later in the five-year SOCAL BRS project.

4) Obtain data to support range monitoring/habitat models

A large biological dataset on southern California marine mammals was obtained through SOCAL-10. We accomplished thousands of sightings of 23 marine mammal species, hundreds of photo IDs of known and new individuals, and collected biopsy and skin samples from numerous species.

9. SOCAL-10 TRANSPARENCY AND PUBLIC IMPACT

The SOCAL BRS project is and will remain committed to openness and transparency of the project and to the timely and effective transmission of results. SOCAL-10 clearly demonstrated this commitment. Open discussions, both in the more than 15 public meetings and through exchange of questions and responses, with conservation interests and other scientists, was a healthy and constructive aspect of the planning and quick-look summary of SOCAL-10. This is a process that will continue throughout the SOCAL-BRS project.

We believe that the scientific data generated by SOCAL-10 will contribute to a greater understanding of biologically important areas off southern California, as well as how marine mammals dive, communicate, and respond behaviorally to different sounds. The preliminary data have already been presented to educational, government, and

conservation organizations to increase public awareness and appreciation of these valuable areas and species. As additional analyses are conducted, the results will continue to be integrated with ongoing, international efforts to better understand behavioral responses of marine mammals to sound. The SOCAL-10 data will continue to be made available through scientific presentations and publications in a timely manner, as well as through various other public outlets to maximize their utility and impact.

10. CONCLUSIONS AND NEXT STEPS

There are three overarching conclusions to be drawn from the SOCAL-10 project.

1. Modification of previous BRS approaches and application in southern California on new species was successful
   - *SOCAL-10 overwhelmingly productive in terms of total number of tags, species, and CEEs completed*
   - *Additional refinements will be made, moving toward the objective of including real operations in a CEE configuration in later years.*
2. Preliminary results indicate observable responses to sonar/noise sounds in some conditions and species (notably Cuvier's beaked whale and blue whales in deep feeding/travel mode
   - *Points to a more complex, species- and/or context-specific type of response than a simple dose-response function based solely on received sound amplitude level*
3. SOCAL-10 data will ultimately enable both the U.S. Navy & NOAA to better fulfill their requirements to understand and assess impacts on marine mammals
   - *First direct measurements on large whales*
   - *Relatively large sample sizes with ability to contrast behavioral states*
   - *First ever controlled measurement on beaked whale sp. most often stranded*

SOCAL BRS next steps

For the five-year overall SOCAL BRS project, SOCAL-11 is expected to include generally similar configuration and objectives as SOCAL-10. The R/V *Truth* is expected to serve as the primary research platform for the scouting and both legs (July-September 2011) and operations are expected to occur in similar general areas as in SOCAL-10 (depending obviously on weather and the distribution of animals). SOCAL-11 is also expected to include a dedicated research platform for passive acoustic monitoring (PAM) for the detection of odontocete cetaceans (primarily beaked whales) in areas off the SCORE range. Additionally, SOCAL-11 will integrated prey measurements using scientific echosounders with tagged whale foraging behavior at fine scales. Finally, an even

smaller and more portable sound source is being developed for SOCAL-11 and will be pilot tested for possible deployment from a medium-sized RHIB.

While clearly subject to change based on the results of SOCAL-11*,* SOCAL-12 is expected to include a possible transition to even smaller research vessels with the capability to deploy longer-term acoustic monitoring tags and cover additional area, in preparation for the possible use of realistic sound sources in CEEs. Also subject to modification, SOCAL-13/14 is at present envisioned to include a combined approach with small vessels using similar deployed sources and, as possible, realistic military sources within the context of CEEs to measure responses in scenarios that are as realistic as possible.