Biological and Behavioral Response Studies of Marine Mammals in southern California ('SOCAL-10')

~ Project Description ~

Introduction

SOCAL-10 is the first phase of a multi-year effort (~2010-2015), called SOCAL-BRS (Behavioral Response Study). This research collaboration is designed to increase understanding of marine mammal behavior and reactions to sound. Direct, scientific information about these responses to different human sounds is limited but critically needed by both regulatory agencies to support informed conservation management decisions and requirements and militaries for effective operational planning to minimize environmental risk (see: NRC, 1994; 2000; 2003; 2005; ICES AGC, 2005; Cox *et al*., 2006, Southall *et al*., 2007; 2009; Boyd *et al*., 2008).

This project extends previous BRS efforts conducted in the Bahamas and Mediterranean Sea in 2007-2009[1] and is being coordinated with related and successful field efforts (*e.g.*, population surveys of Navy range areas, satellite tagging before active sonar operations) underway in southern California. SOCAL-10 will use controlled exposure experiments (CEEs) to carefully measure behavioral responses of individual animals to sound exposure.

It is part of an integrated, international effort using similar *experimental* approaches and *observational tracking* of animals during real activities (*e.g.*, see: DiMarzo, *et al.*, 2008; Tyack *et al.,* 2009). Each method has pros and cons. For instance, the experimental approaches using CEEs have as yet not included full scale sources, raising issues of how a scaled-down source may affect measurements of responses in relation to the real thing; they are also limited by small sample size due to the challenges in meeting all the specified experimental protocols. Similarly, merely observing what animals do in the context of realistic exercises without modifying them to focus on specific experimental subjects, though very useful in

[1] see additional material at: http://www.sea-inc.net/science/#brs

involving real operations and larger numbers of subjects, lacks certain scientific controls and necessary detail on individual responses. Thus, it seems clear that neither approach will provide a complete answer - a comprehensive approach with opportunistic and experimental methods is proving the most appropriate and useful in addressing some of these difficult questions.

SOCAL-10 includes collaborations among scientists, acousticians, and engineers from NOAA, academic and private research laboratories, and U.S. Navy-supported organizations (below).

This collaboration is designed to advance our understanding of southern California marine mammals and gain information about their responses to sound. The results are critically important to entities who produce sounds for a particular purpose (*e.g.*, military sonar to find submerged objects) that may have unintended negative consequences on marine species, as well as for regulatory agencies responsible for managing protected species. SOCAL-10 is being supported by several organizations within the U.S. government (below) facing these issues and seeking better data to inform decision-making.

Background

Photo courtesy of NOAA National Marine Mammal Laboratory

Marine mammals use sounds for many important things, such as finding food, raising their young, finding mates, avoiding predators, and finding their way around the large, generally dark ocean. They are primarily acoustic animals just as many land animals, including us, are primarily visual. Consequently, sounds in their environment can interfere with communication or significantly alter their behavior in other ways.

Photo courtesy of NOAA, National Marine Fisheries Service

Global concern about noise impacts relates mainly to interference (or "masking") of important sounds from industrial sounds, primarily large ships (see Southall *et al.*, 2005; Clark *et al*., 2009) or subtle, chronic impacts associated with sustained disturbance (*e.g*., Bejder *et al.*, 2006). The only known case where acute exposure to sound has led to lethal effects involves atypical mass strandings of beaked whales during naval sonar exercises (see Cox *et al*., 2006 for a review). These events, which seem to be rare given the frequency of operations, share some similarities in geography, environmental conditions, and the species involved (beaked whales most commonly).

Photo courtesy of NOAA, National Marine Fisheries

While there is clearly reason for concern regarding sound impacts on marine mammals and this concern seems particularly valid for certain kinds of active sonar systems, there is extremely little direct information on which to gauge the overall magnitude of potential problems and base operational and conservation management decisions. We lack a basic understanding of what causes these events, how frequent they may be, and, most importantly, what can be done to reduce the risk of subsequent events. Better data are sorely needed.

The top research priority identified by Cox *et al*. (2006) regarding the beaked whale and sonar issue is to obtain direct measurements of responses using CEEs. Most recent reports and research recommendations on marine mammals and underwater sound (*e.g.*, NRC, 2003; 2005; ICES AGISC, 2005;

Southall *et al.*, 2007; 2009; Boyd *et al.*, 2008) agree with the Cox *et al*. (2006) conclusions and recommended an experimentally-based approach to addressing the need for new and reliable data on how beaked and other whales respond to sonar and other underwater anthropogenic sounds. For example the position paper of the European Science Foundation Marine Board (Boyd *et al*., 2008) in setting priorities states:

"*Controlled exposure experiments have been suggested as a high research priority. The analyses suggest that characterizing the dose response relationship is an important pre-cursor to assessing the impacts on either individuals or populations. It further shows that opportunistic experiments are unlikely to be valuable unless there is an appropriate measure of the received sound at the level of the individual marine mammal*."

Similarly, Southall *et al*., (2007) note that the lack of data on exposures that disrupt behavior in beaked whales has prevented the kinds of measures taken for other marine mammals (*e.g.*, porpoises) that have proven to be particularly sensitive to sound exposure, stating:

"*The controlled exposure experiments outlined above are essential to revealing the conditions and responses underlying this effect. Until such research is conducted, deriving science-based exposure criteria specifically for beaked whales or other deep-diving cetaceans exposed to active sonar will prove difficult or impossible*."

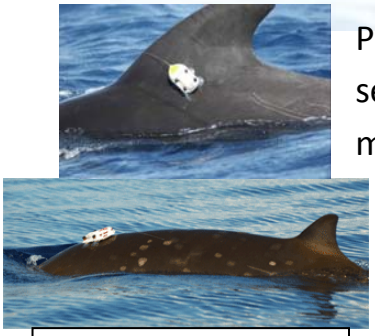
The SOCAL BRS effort, beginning with SOCAL-10, is designed to specifically and directly address these difficult and important issues, while ensuring the safety of experimental subjects and others in the study area, and in doing so to also provide some important basic biological data that are similarly lacking.

Related Behavioral Response Studies

There has been considerable effort to measure diving, communication, and other behavior in marine mammals, particularly in the last decade (*e.g.*, see: Johnson *et al*., 2009; Tyack, 2009). Many of these studies have included use of the use of digital acoustic tags, such as the "DTags" developed at the Woods Hole Oceanographic Institution (WHOI) that have proven to be invaluable tools particularly for studying deep-diving species such as beaked whales that are seldom visible at the sea surface (Johnson and Tyack, 2003). These specialized acoustic listening and movement sensors are attached to marine mammals using suction cups and provide a unique window into their behavior and responses to events in their environment. The deployment of DTags provided the capability to obtained critical baseline data on diving and foraging in beaked whales and other species (Madsen *et al*., 2005; Tyack *et al*., 2006; Tyack, 2009) and laid the foundation for future work involving CEEs in these and other species.

The UNOLS research vessel *Roger Revelle* was used in BRS-08

During 2007 and 2008, marine mammal behavioral response studies (called "BRS 07-08") took place in the Bahamas with a collaboration of inter-disciplinary researchers similar to that being used in SOCAL-10. A related effort (called "MED-09") followed in the western Mediterranean Sea the following year, which built on a series of research projects since 1999 as part of the NATO Undersea Research Center projects Sound and Living Marine Resources (SOLMAR) and Marine Mammal Risk Mitigation[2].



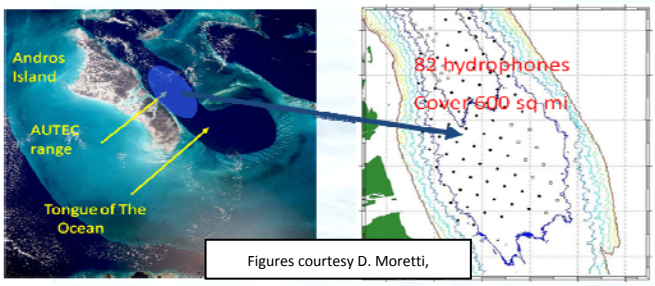
[photo credits: A. Friedlaender, obtained under U.S. NMFS permit # 1121-1900]

Prior to BRS 07-08 there were no direct studies of how seemingly sensitive species such as beaked whales react to sounds like military sonar. BRS-07/08 researchers wanted to measure baseline behavior and reactions to these kinds of signals in order to better predict impacts and reduce the risk of future strandings. However, researchers did not want to harm animals while studying them and thus developed and used precautionary

[2] See: http://solmar.nurc.nato.int/solmar/index.html

safety procedures, shut-down criteria, and monitoring methods to ensure the experiments were conducted safely and without harming subjects. Additionally, a significant amount of effort was put into studying the baseline diving and foraging behavior or these amazing, extreme animals without sound exposure, so that any changes in these patterns resulting from sound exposure could be identified and statistically tested.

During BRS-07/08, and using techniques and tools from these related international research projects, a specialized, inter-disciplinary team of scientists used DTags to measure the behavior of four cetacean species (including beaked whales, pilot whales, false killer whales, and melonheaded whales), including how they reacted to intentional sound exposures. BRS 07-08 sought to learn more about beaked whales and other cetaceans in a unique area of the Bahamas called the Tongue of the Ocean, which is a very deep basin to the east of Andros Island surrounded by shallow flats and shoals. This area is home to several species of beaked whales and it also houses a specialized underwater listening range (called the Atlantic Undersea Testing and Evaluation Center, or "AUTEC") used by the U.S. Navy and its allies to train and test new equipment. Scientists and engineers have tuned these listening sensors (called "hydrophones") to track different species of marine mammals over quite large areas using the sounds that they make and began working with marine mammal researchers to track and identify them. The tools had advanced to the point where carefully conducted CEEs to investigate whether and how different species responded to human sounds were now possible.

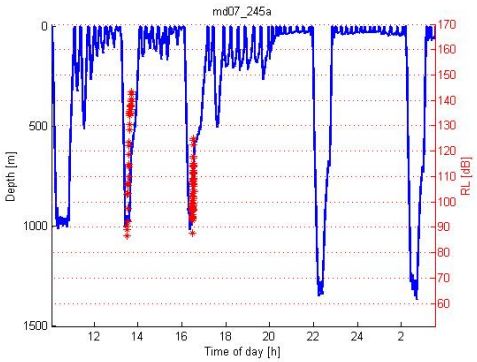


Figures courtesy D. Moretti,

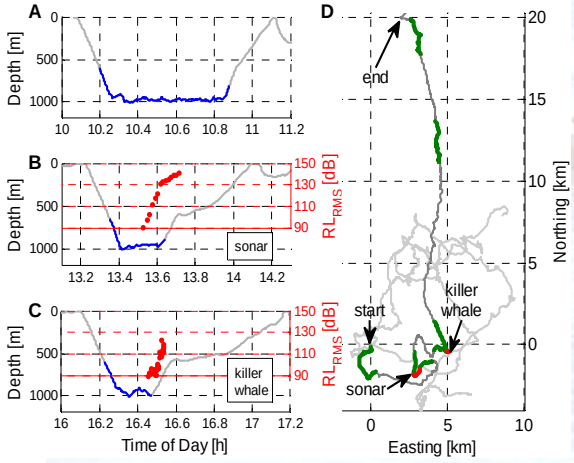
Controlled Exposure Experiments (or "CEEs") are studies in which the behavior of test subjects is measured before, during, and after controlled sound exposures. Different behavioral patterns can be statistically compared without and with different kinds of sounds to identify responses.

During the course of BRS 07-08, a total of 16 DTags were attached to individuals of the four focal species. In addition to a large amount of sighting and acoustic detection data and baseline diving behavior, CEEs were conducted with various combination of simulated military, mid-frequency sonar sounds, killer whale calls, and

"control" noises with a total of four pilot whales, two beaked whales, two false killer whales, and one melon-headed whale. During these exposure studies, the Dtags obtained interesting and important results about how the study animals behaved before sounds were played and how they reacted to them while they were on and afterwards. The figure to the right shows a dive record of a beaked whale with one deep dive before any sounds, a second dive with simulated sonar, a third dive with killer whale sounds, and two post-exposure "recovery" dives. Red symbols on the second and third dives indicate sound exposures in terms of the received sound level, or what would be perceived as "loudness", at the whale (units on right axis are underwater sound levels).

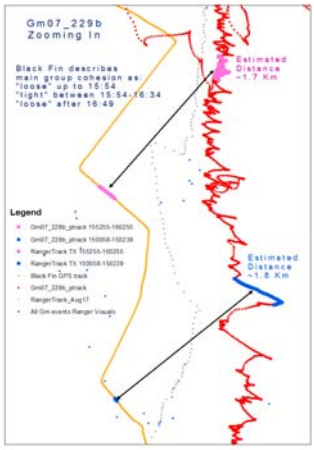


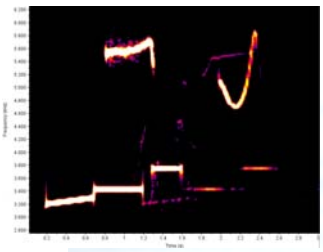
If we blow up the time axis of the first three of these dives to see them in greater detail (A, B, C in figure to the left), there are clear differences in behavioural patterns before, during and after sound exposure. The animal came up sooner, made less clicking sounds associated with feeding (highlighted in blue), and returned to the surface slower and at a shallower angle during the exposure dives (B and C) than during the baseline dive before sound (A). If we look at the whole sequence in a plan view (D, as if looking down from high above the whole track of the animal over all dives), we can see the three deep dives highlighted in green and that, following the killer whale sound exposure the beaked whale swam essentially directly away from the site of the experiment for some 20 km until the Dtag detached around four in the morning.



In contrast to this kind of reaction, also generally seen in the other beaked whale CEE using a noise control sound, exposures to pilot whales and the other cetaceans tested yielded much less dramatic kinds of responses. These animals tended to make slight changes in orientation, vocal, and social behavior, but did not

exhibit the clear and statistically significant changes in behavior seen in the beaked whales. The figure to the right shows one of the pilot whale CEEs and the track of the whales (in red) was not perceptibly altered during simulated sonar (in blue) and killer whale sounds (in pink), though some changes in social cohesion were observed. Interestingly, on some occasions, false killer whales actually appeared to respond vocally to the sounds played to them underwater, mimicking them as in the case of the figure to the left showing the simulated sonar signal (stepped, three-part tone) and a tone made just afterwards by the whale followed by a whistle.





The data from BRS 07-08 were quite significant in being the first direct measurements of responses of cetaceans, including beaked whales, to simulated military, mid-frequency sonar signals like those involved in previous stranding events. Additionally, despite the concerns about possible negative impacts, important results (hinting at relatively stronger reactions in beaked whales relative to other species) were obtained without any apparent harm to subject animals or others in the area (extensive post-monitoring was done and subjects were sighted later behaving normally). But the results from the Bahamas were limited in the number of CEEs that were obtained, simply because of the extreme limitations on the weather conditions required to do these studies (very calm seas). The MED-09 study was similarly limited by the ability to tag focal marine mammals, although several major accomplishments were made in that project in terms of integrating acoustic and visual sensors.

Additional studies remain needed to identify whether the initial observations made in BRS were generally applicable in other circumstances, and to extend these studies to previously untested marine mammal species, such as the large baleen whales and seals/sea lions. The desire to expand studies to additional species that may be affected by human sounds including military sonar was a primary motivation for concentrating a dedicated BRS effort in southern California, beginning with SOCAL-10.

SOCAL-10 Objectives

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

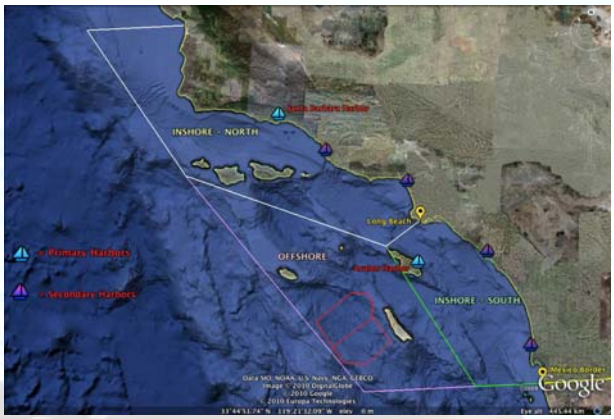
(2) Conduct CEEs using similar exposure methodology from previous BRS;

(3) Determine optimal BRS configuration for scaled playback configurations and in realistic/actual military sources in subsequent (2012-15) years;

(4) Obtain basic biological, behavioral, and foraging ecology data for marine mammals to support range monitoring efforts and/or habitat models.

Timing and Operational Areas

SOCAL-10 will take place from late August through September in three primary operational areas shown here: inshore north; inshore south; and offshore areas. The exact timing and location of SOCAL-10 within these operational areas will be determined largely by finding the right combinations of good weather and animals.

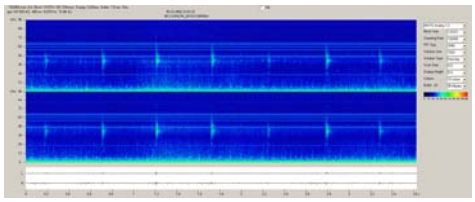


SOCAL-10 Multidisciplinary Teams

SOCAL-10 will include highly experienced scientists and engineers, 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 are organized into specialized teams, each serving specific, inter-related functions.

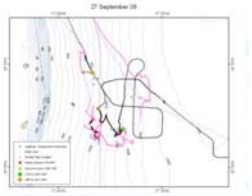
Visual observers are experienced in sighting marine mammals up to several miles away with powerful binoculars. They will search for subjects and, once they are tagged, monitor animals during CEEs.

Photo identification will be used to catalog and keep track of individuals and groups sighted and involved in CEEs.



Passive acoustic observers will use different listening systems, in certain conditions, 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 will carefully approach and deploy acoustic monitoring tags with non-invasive suction cups; tag teams will also provide visual monitoring of focal groups that have been tagged during baseline dives and CEEs and will report all behavioral observations.



Geographical Information Systems (GIS) engineers will integrate information, including vessel position, visual sightings, and environmental data, for real-time presentation on maps and synchronized archive of all SOCAL-10 activities and measurements.

Sound source technicians will operate the specialized underwater speaker that will be used to play experimental sounds during CEEs.

Experimental Protocols

In this section, the experimental protocols for CEEs on focal individuals that are being monitored with acoustic and movement tags (our primary approach) are described. Additionally, the protocols for a somewhat new approach for obtaining behavioral response data on smaller, pelagic odontocete cetaceans (*e.g.*, offshore dolphins) are described. For both experimental methods, the conditions for beginning, completing, and monitoring following CEEs are given, as well as the shut-down criteria whereby sound transmissions would be terminated.

"TAGGED INDIVIDUAL" CEE PROTOCOLS

The objective of the tagged individual studies is to obtain baseline behavioral data and conduct CEEs to focal individuals/groups of odontocetes in which at least one animal is carrying a suction cup acoustic tag. The following conditions must be met in order to proceed to the CEE portion of the experiment:

- Sufficient time since tag deployment to reduce attachment disturbance effects and obtain a reasonable amount of baseline behavioral data. During BRS-07/08, this was defined for beaked whales as at least one deep foraging dive and complete surface sequence; this criterion will be used for SOCAL-10 for beaked whales, as well. A comparable interval (ideally two hours since tag-on) will be used for the mysticete species that will be of primary focus in SOCAL-10 and other odontocetes as well;

- During this interval, obtain all possible visual observation on baseline behavior from source vessel and RHIBs;

- Determine/confirm that *no calves in group are neonates*, as defined within the NMFS scientific research permit (proposed as the presence of fetal folds for non-ESA listed species and estimated age of 6 months for ESA-listed species in the permit application);

- 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.

Provided that these conditions have been met, as agreed upon by the chief scientist and co-investigators in the field, SOCAL-10 researchers would then proceed to carrying out 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 (variable depending on focal species distribution and deflection angle);

- 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.;

- Protocol is one exposure type per focal individual/group, with sufficient pre-exposure baseline and as much post-exposure “recovery” as possible until tags detach.

Before, during, and after each CEE phase, the following data will be obtained:

- Archival acoustic tags are primary data collection in this mode, providing movement and acoustics of animals and received sound exposures at the animals;

- However, all visual observation data are critical as well and source vessel visual team will record position, orientation, social configuration, and other parameters of focal individual/group (*e.g.*, respiratory behavior, swim speed), as possible;

- Source visual team will also monitor to insure no marine mammals inside 200m shutdown zone and provide any observations of responses of other marine mammal groups (as possible without conflicting with observations of focal individual/group;

- RHIB teams will provide additional visual observation support, along same lines as described above for source vessel observations;

- RHIB teams will also collect prey field data, as possible, using existing depth sounders (50 kHz and 200 kHz sources) – either or both may be used during large whale (mysticete) focal follow/CEE but just the 200 kHz sources will be used when focal species are small cetaceans including dolphins, beaked whales, etc. (odontocetes).

During CEEs the following safety shut-down protocols will be used to terminate active sound exposures:

- *Any marine mammal inside 200m shut-down zone* around source vessel during transmissions;

- Visual detection from source boat or RHIBs of focal group or incidentally-exposed marine mammals exhibiting:

    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 may be 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 begins to become clearly separated during sound exposure* (as determined by one of the principal investigators based on the input of trained marine mammal biologists observing the animals), sound transmissions will be terminated.

- For beaked whale CEEs on the U.S. Navy SCORE range in SOCAL-10, we would use the same criterion as in BRS-07/08:

    o After animal starts foraging dive, commence exposure soon after animal starts clicking;

    o Terminate exposure when focal group is determined to cease clicking (3 min criteria);

    o Subsequent years will likely include options for continuing or initiating exposures during/though surface sequences

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

- Source boat and/or RHIB visual teams will maintain visual (and passive acoustic monitoring (PAM), if applicable) monitoring of focal groups for a minimum of one hour post CEE;

- Source boat will maintain visual/VHF radio monitoring of focal animal as long as possible following CEE, but at least on Leg I there will generally not be nighttime tracking of tags/focal animals;

- If there are multiple individuals with tags in a group and the animals stay in the same group, the source boat will stay with them. If the individuals separate, the source boat will go with one and one or both RHIBs will monitor the other.

"TAGLESS" CEE PROTOCOLS

There are certain species of considerable interest in terms of measuring behavioral responses to sound exposure that are currently quite difficult or impossible to tag with existing acoustic tagging technology. Some of these species (*e.g.*, common dolphins) occur in large schools and, due to their relative abundance, make up a relatively large portion of animals that are regularly exposed to military sonar in the context of training exercises. While they may not be amenable to acoustic tagging with current technologies, and thus the primary methods described for "tagged individual" CEEs described above, protocols have been developed for conducting CEEs with groups as the focal unit while still

obtaining biologically-meaningful and operationally-relevant behavioral response data.

The objective of these "tagless" CEEs is to obtain response data from groups of cetaceans (primary focus is small, pelagic odontocetes) in which no animals are carrying a suction cup acoustic tag, but one or more may be tagged with satellite-tracking tag or other monitoring device attached by separate research efforts. SOCAL-10 may have operational awareness on animals tagged in other projects (especially those involving researchers also included in SOCAL-10) and may leverage this knowledge to obtain some individual movement and response data in a "tagless" playback scenario. The following conditions must be met in order to initiate a "tagless" CEE:

- Beaked whales will not be used in tagless playback scenarios in SOCAL-10, and mysticetes will generally only be used in situations where acoustic tag attachment is not possible and/or where another tag type is attached to allow analysis of movement data);

- Identify and photo-ID focal group for tagless playback and monitor behavior using source boat and RHIB visual capabilities (and PAM as possible) for a minimum of 45 min. to 2 hr., as possible (same criterion as for tag playbacks);

- During this interval obtain all possible visual observation on baseline behavior from source vessel and RHIBs;

- Determine/confirm that *no calves in group are neonates*, as defined within the NMFS scientific research permit (proposed as the presence of fetal folds for non-ESA listed species and estimated age of 6 months for ESA-listed species in the permit application);

- 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.

The experimental procedures and shut-down protocols during CEEs are essentially the same as those described above for tagged individual CEEs. However, the data to be obtained are quite different and include the following:

- Any tags attached by other research projects, may ultimately provide some data on movements and exposures, but visual observation data are essential in real-time here (and all we will have if no ancillary tags attached);

- Source vessel visual team will record position, orientation, speed of travel; social configuration, and other parameters of focal individual/group as possible;

- Source visual team will also monitor to insure no marine mammals inside 200m shutdown zone and provide any observations of responses of other marine mammal groups (as possible without conflicting with observations of focal individual/group;

- RHIB teams will provide additional visual observation support, along same lines as described above for source vessel observations;

- RHIB teams will also collect prey field data, as possible, using existing depth sounders (50 kHz and 200 kHz sources) – either or both may be used during mysticete focal follow/CEE but just the 200 kHz sources will be used when focal species are odontocetes.

Finally, the following post-CEE monitoring will be conducted following "tagless" playback experiments:

- Source boat and/or RHIB visual teams will maintain visual (and PAM if applicable) monitoring of focal groups for a minimum of one hour post CEE;

- If the focal group separates prior to this period, the source boat and RHIBs will diverge to try and monitor the groups as possible.

Safety and Stranding Protocols

SOCAL-10 will make every effort to ensure the safe operation of all research vessels and the safety of all personnel. SOCAL-10 will comply with all state and federal international laws and coordinate with state and federal agencies (*e.g.*, California Coastal Commission). The project also includes specific precautionary measures to ensure the safety and welfare of marine mammal subjects[3]. These

[3] Each of these safety protocols has been detailed in a U.S. NMFS scientific research permit application (#14534)

include criteria for avoiding certain marine mammals (*e.g.*, neonate calves), safety measures for close approaches and tagging, and specific conditions for sound transmissions during CEEs (*e.g.*, terminating sound transmissions if animals are within 200 m or when any abnormal behaviors are detected).

There is little reason to believe that SOCAL-10 will result in harm to marine mammals, based on safe and successful efforts in BRS 07-08, but it is only responsible to have stranding response protocols. Strandings are common in California and could occur in the same area, even if there is no correlation with SOCAL-10. In coordination with stranding networks, response contingencies are in place to ensure rapid reporting of any stranded marine mammal, facilitate response and investigation, and assess any possible relationship to SOCAL-10.

SOCAL-10 Scientific and Public Impact

SOCAL-10 is committed to openness and transparency of the project and to the timely and effective transmission of results. Open discussions, both in public meetings and through exchange of questions and responses, with conservation interests and other scientists has been a healthy and constructive aspect of the planning of SOCAL-10 and is a process that will continue throughout the project.

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

References

Bejder, L., A. Samuels, H. Whitehead, N. Gales, J. Mann, R. Connor, M. Heithaus, J. Watson- Capps, C. Flaherty, and M. Krützen. (2006). Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. Conservation Biology 20: 1791-1798

Boyd I.L., Brownell R., Cato D., Clark C., Costa D., Evans P., Gedamke J., Gentry R., Gisiner R., Gordon J., Jepson P., Miller P., Rendell L., Tasker M., Tyack P., Vos E., Whitehead H., Wartzok D., and Zimmer W. (2008). The effects of anthropogenic sound on marine mammals: A draft research strategy. European Science Foundation, Marine Board (Oxford, England, United Kingdom).

Clark C.W., Ellison W.T., Southall B.L., Hatch L., Van Parijs S.M., Frankel A., Ponirakis D. (2009). Acoustic masking in marine ecosystems: intuitions, analysis, and implication. Marine Ecology Progress Series 395: 201-222.

Cox, T. M., Ragen, T. J., Read, A. J., Vos, E., Baird, R. W., Balcomb, K., Barlow, J., Caldwell, J., Cranford, T., Crum, L., D'Amico, A., D'Spain, G., Fernández, A., Finneran, J., Gentry, R., Gerth, W., Gulland, F., Hildebrand, J., Houser, D., Hullar, T., Jepson, P. D., Ketten, D., MacLeod, C. D., Miller, P., Moore, S., Mountain, D., Palka, D., Ponganis, P., Rommel, S., Rowles, T., Taylor, B., Tyack, P., Wartzok, D., Gisiner, R., Mead, J. and Benner, L. (2006). Understanding the impacts of anthropogenic sound on beaked whales. Journal of Cetacean Research and Management 7: 177-187.

DiMarzio N., Moretti D., Ward J., Morrissey R., Jarvis S., and Izzi A. (2008). Passive acoustic measurement of dive vocal behavior and group size of Blainville's beaked whale (*Mesoplodon densirostris*) in the Tongue of the Ocean (TOTO). Canadian Acoustics 36: 166-173.

ICES AGISC. (2005). Ad-Hoc Group on the Impact of Sonar on Cetaceans. International Council for the Exploration of the Seas, Copenhagen, Denmark.

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.

Johnson M., Aguilar de Soto N., and Madsen P.T. (2009). Studying the behaviour and sensory ecology of marine mammals using acoustic recording tags: a review. Marine Ecology Progress Series 395: 55-73.

Madsen P.T., Johnson M., Aguilar DeSoto N., Zimmer W.M.X. and Tyack P. L. (2005). Biosonar performance of foraging beaked whales (*Mesoplodon densirostris*). Journal of Experimental Biology 280:181-194.

U.S. National Marine Fisheries Service (NMFS). (2009). Taking and Importing Marine Mammals; U.S. Navy's Atlantic Fleet Active Sonar Training (AFAST). Federal Register 74(16): 4844-4885, January 27, 2009.

National Research Council (NRC). (1994). Marine Mammals and Low-Frequency Sound. National Academy Press, Washington, D.C.

National Research Council (NRC). (2000). Marine Mammals and Low-Frequency Sound, Progress Since 1994. National Academy Press, Washington, D.C.

National Research Council (NRC). (2003). Ocean Noise and Marine Mammals. National Academy Press, Washington D.C.

National Research Council (NRC). (2005). Marine Mammal Populations and Ocean Noise: Determining When Noise Causes Biologically Significant Effects. National Academy Press, Washington, D.C.

Southall, B. L. (2005). *Shipping Noise and Marine Mammals: A Forum for Science, Management, and Technology*. Final Report of the National Oceanic and Atmospheric Administration (NOAA) International Symposium 18-19 May 2004, Arlington, Virginia, U.S.A. Silver Spring, MD: NOAA Fisheries Acoustics Program.

Southall, B. L., A. E. Bowles, W. T. Ellison, J. J. Finneran, R. L. Gentry, C. R. Greene Jr., D. Kastak, D. R. Ketten, J. H. Miller, P. E. Nachtigall, W. J. Richardson, J. A. Thomas, and P. L. Tyack. (2007). Marine mammal noise exposure criteria: Initial scientific recommendations. Aquatic Mammals 33: 411-521.

Southall, B., Berkson J., Bowen D., Brake R., Eckman J., Field J., Gisiner R., Gregerson S., Lang W., Lewandoski J., Wilson J., and Winokur R. (2009). Addressing the Effects of Human-Generated Sound on Marine Life: An Integrated Research Plan for U.S. federal agencies. Interagency Task Force on Anthropogenic Sound and the Marine Environment of the Joint Subcommittee on Ocean Science and Technology. Washington, DC.

Tyack P. L. (2009). Acoustic playback experiments to study behavioral responses of freeranging marine animals to anthropogenic sound. Marine Ecology Progress Series 395: 187-200.

Tyack, P. L., Johnson, M., Soto, N. A. d., Sturlese, A. and Madsen, P. T. (2006). Extreme diving behaviour of beaked whale species known to strand in conjunction with use of military sonars. Journal of Experimental Biology 209: 4238-4253.