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CRUISE REPORT FOR PASSIVE ACOUSTIC MONITORING COMPONENT OF THE 2013 SOCAL-BEHAVIORAL RESPONSE STUDY

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INTRODUCTION

The SOuthern CALifornia-Behavioral Response Study (SOCAL-BRS) is a multi-institutional project to determine the reaction of cetaceans to mid-frequency (~3 kHz) Navy sonar signals in Southern California waters. The purpose of the Passive Acoustic Monitoring (PAM) component of the SOCAL-BRS is to find beaked whales and sperm whales as test subjects. Secondary objectives include: detecting other marine mammals in the study area; recording and measuring test vessel noise, ambient noise, and the simulated Navy sonar signal at varying distances from the source vessel.

Our 2013 field study is the fourth year of this project. Leg 1 included two primary vessels: the source and visual search platform (M/V *Truth*) and a stand-alone PAM sailing research vessel (R/V *Derek M. Baylis*). On Leg 1, the PAM vessel carried three acousticians and three visual observers (with two of each on-duty at a time). On Leg 2, the towed hydrophone effort was reduced to two acousticians and was aboard the M/V *Truth*. During both legs of the cruise the M/V *Truth* also served as a base for two Rigid Hull Inflatable Boats (RHIBs) that were used for tagging and tracking. Animals were tagged using D-tags (which record behavior and acoustic data) and exposed to simulated Navy sonar signals transmitted from the M/V *Truth* and actual Navy sonar transmitted from Navy warships.

METHODS

Leg 1

On Leg 1 (23 July – 4 August 2013), the PAM component of the SOCAL-BRS survey was conducted on a 65’ Wyliecat motor-sailer, the R/V *Derek M. Baylis* (Fig. 1a). The vessel departed anchorage each morning between 0400 and 0600 to transit to the day’s study area with in Southern California waters. A towed hydrophone array was deployed upon entering the study area, and acoustics personnel initiated survey effort immediately. Visual observers initiated effort once there was sufficient daylight. The vessel surveyed until target animals were detected, or until 1600, when it would transit to an anchorage. The geographic area varied daily, based on the weather and sea state conditions, as well as the intended survey track of the M/V *Truth* (Fig. 1b) and RHIB tagging team.

Visual observation for cetaceans was conducted by personnel from the bow of the R/V *Derek M. Baylis* using 7x handheld binoculars and naked eye during daylight hours. Observers would scan the area 180° forward of the vessel in search of cetaceans. When cetaceans were detected, basic information regarding the location and species identity were logged in a computer.

A hydrophone array was towed ~100 m behind the R/V *Derek M. Baylis* to detect, localize, and classify sounds associated with cetaceans (Fig. 1c). The primary array was a tetrahedral array, which provided improved localization capabilities. A linear towed array (Oil 8) was used as needed or when vessel speeds were greater than 6 knots (Table 1).

Leg 2

On Leg 2 (11 Sept – 24 Sept 2013), the PAM component of the SOCAL-BRS survey was conducted on a 65' diving vessel, the M/V *Truth*. This vessel departed anchorage each morning between 0600 and 0700 to transit to the study area. A linear hydrophone array was deployed 200 m behind the survey vessel when the vessel reached the study area acoustics personnel initiated survey effort immediately. The primary array was a linear towed array (Oil 10), which allowed the M/V *Truth* to travel between 8 and 10 knots (Table 1). Acoustic survey effort ended when the survey vessel stopped to conduct an acoustic exposure or control sequence (Southall et al. 2012). The study area varied daily, based on the weather and seas, as well as the intended survey track of the M/V *Truth* and RHIB tagging team.

Visual observation for cetaceans was conducted by four personnel (Cascadia Research Collective) from the flying bridge of the M/V *Truth* using 7x handheld binoculars and naked eye during daylight hours. Observers would scan the area 180° forward of the vessel in search of cetaceans. When cetaceans were detected, basic information regarding the location and species identity were logged in a computer.

Recording System for Both Legs

Signals from the hydrophone array were digitized using a Fireface UC audio interface, and recordings of all channels were made at a 192 kHz sampling rate using Pamguard software (Fig. 1d). Two acousticians monitored for cetacean sounds using headphones (aural) and Pamguard software (visual). The detection and identification of beaked whales relied on several features within Pamguard, including the automated click detector, click classifiers (Keating & Barlow 2013), beaked whale alarm, the surface bounce module, the spectrogram, the waveform, and Wigner plot.

When beaked whales were detected, the acoustics team tracked animals using localization methods within Pamguard. Basic detection information was provided to the chief scientist aboard the M/V *Truth*, who would then make a decision regarding tagging efforts based on circumstances. Although beaked whales and sperm whales were the top priority species for the 2013 SOCAL-BRS, other species were considered for tagging efforts.

Autonomous Recorder Deployments

During both legs of the Behavior Response Study several types of autonomous drifting recorders were deployed (Table 2). A Loggerhead DSG-Ocean acoustic datalogger and a custom-built Drifting Acoustic Spar Buoy Recorder (DASBR) were deployed to measure vessel noise of the M/V *Truth*, R/V *Derek M. Baylis*, and RHIBs, ambient noise levels in the vicinity of acoustic playback experiments, and received sound levels at varying distances from the real and simulated sound sources. A CPOD click logger was deployed with a DASBR to compare the ability of these two instruments to detect cetacean click sounds. In addition, a custom-built Expendable Buoy (XB) was deployed to track the movement of ocean currents within the study area of Leg 1.

RESULTS

Leg 1

Over 1,250 km of acoustic survey effort was conducted during Leg 1 (23 July – 4 August) of the 2013 SOCAL-BRS survey aboard the PAM survey vessel. Survey effort alternated use of the linear oil array and the tetrahedral array (Table 1). The tetrahedral array suffered a failure on July 31st caused by sea water intrusion on the connectors. A linear array was used for the remainder of the survey.

A total of 116 cetaceans were detected from the R/V *Derek M. Baylis*, of which 89 were detected using acoustic methods (Table 3). Detections included long-beaked common dolphins (*Delphinus capensis*), unidentified common dolphin species (*Delphinus* spp.), bottlenose dolphins (*Tursiops truncatus*), Risso's dolphins (*Grampus griseus*), blue whales (*Balaenoptera musculus*), fin whales (*Balaenoptera physalus*), sperm whales (*Physeter macrocephalus*), and two species of beaked whales (*Ziphius cavirostris* & *Berardius bairdii*) (Table 3, Figs. 2 & 3). There were a total of 12 beaked whale detections on 7 of the 13 survey days; all beaked whales except one were detected using acoustic methods (Table 3, Fig. 3). Two acoustic detections of Cuvier's beaked whales (*Ziphius cavirostris*) were not sighted by our visual team; however species identification was confirmed by the M/V *Truth* and the U.S. Navy SCORE team. Acoustic species classification of Baird's beaked whale (*Berardius bairdii*) was determined by characteristics outlined by (Yack *et al.* 2013); this not confirmed by visual observation. Several beaked whale detections were approached for tagging efforts; an example is described in detail below.

On July 28th two groups of Cuvier's beaked whales were acoustically detected by the team on the R/V *Derek M. Baylis* and visually confirmed by observers on the M/V *Truth*. Efforts were made to tag these animals, but no tags were attached. We returned to the same location on the morning of August 29th and a group of Cuvier's beaked whales were visually detected from the R/V *Derek M. Baylis* at 9:27, tagged via RHIB at 10:48 with a suction cup D-tag, and acoustically detected by the team on the R/V *Derek M. Baylis* at 11:22. These whales were then monitored visually and acoustically for the next 8 hours during which a second group of beaked whales were acoustically detected by the team on the R/V *Derek M. Baylis* and confirmed by the U.S. Navy SCORE team. During this observation period a Navy ship approached the area and performed a controlled exposure experiment (CEE) (Southall et al. 2012). This was the only detection by the R/V *Derek M. Baylis* of Navy sonar throughout the survey.

One sperm whale (an individual nicknamed 'Mango' in previous years) was acoustically detected and visually confirmed on August, 4th through photo identification. No tagging efforts were executed with this animal due to its previous exposure in the study. This animal has been detected at least once a field season for every year of the project in the California Current.

Leg 2

Over 925 km of acoustic survey effort was conducted during Leg 2 (11 Sept – 24 Sept 2013) of the 2013 SOCAL-BRS survey aboard the M/V *Truth*. The PAM component aboard the M/V *Truth* had a total of 91 acoustic detections of cetaceans (Table 4). Detections included long-beaked common dolphins, short-beaked common dolphins, unidentified common dolphin species, bottlenose dolphins, Risso's dolphins, and sperm whales (Table 4, Figs. 4 & 5). There were no acoustic detections of beaked whales and as a result the focus shifted to a secondary species for the project (Risso's dolphins). There were a total of 29 Risso's dolphin detections on 8 of the 10 survey days; (Table 4, Fig. 5). Several detections were approached for tagging efforts, which resulted in both exposure and control sequences (Southall et al. 2012).

DISCUSSION

Eleven groups of beaked whales were acoustically detected on Leg 1 (in July and August) and none were acoustically detected on Leg 2 (in September). Approximately 30% more acoustic effort was logged on Leg 1, which might explain part of this difference. In 2012 (Barlow *et al.* 2014), a similar higher detection rate of beaked whales was seen on the earlier leg (9 in July and August) than on the later leg (2 in October). If beaked whale acoustic detections were all independent, these seasonal differences would be statistically significant, but in reality one detection can lead to a concentration of effort and an increased probability of subsequent detections. Nonetheless, data are suggestive a of movement of beaked whales out of our primary 2012 & 2013 operating area (the Catalina Basin) as summer turns to fall. Additional research is needed to verify this trend over more years.

The tetrahedral hydrophone array performed well during Leg 1 of 2013, but data from hydrophone elements was gradually degraded with use of this array. This array allowed us to resolve the left/right ambiguity that is typical of linear arrays and allowed us to determine downward bearing angles (slant angles) which is particularly important for tracking deep-diving cetaceans. When the internal connectors were examined at the end of the cruise, saltwater intrusion was found to be the likely cause of the decreased performance. Vibration probably loosened the connectors. The advantages of the tetrahedral array clearly show the value of developing a more robust design that can be towed at 10 knots without shaking itself apart.

This was the first year that we tried towing with a 200 m tow cable from the M/V *Truth*. In prior years we used a 100 m tow cable and found that vessel noise overwhelmed our signals at speeds greater than ~6 knots. This year we were able to tow at 10 knots with similar or lower levels of vessel noise than we experienced before at 6 knots. The longer tow cable is strongly recommended for future SOCAL-BRS surveys. When towing from the R/V *Derek M. Baylis*, vessel noise was not a concern at 9-10 knots even with the shorter 100 m tow cable.

In 2013, the visual team on the Baylis (Leg 1) was particularly effective at finding beaked whales and in re-locating beaked whales that had been seen previously. Nothing about the observer stations had changed to explain the improvement over 2012 sightings from the same vessel. Clearly, having an additional vessel with skilled visual observers contributed to the overall success of the 2013 SOCAL-BRS project.

ACKNOWLEDGEMENTS

We thank the captain and crew of the R/V *Derek M. Baylis* (Gabe, Pat, Mark, and Julia) and of the M/V *Truth* (Thomas, Hunter, Kelly, and Sam) for their hard work and positive attitude. We also thank the visual observers (Sophie Webb, Jeff Moore, and Karin Forney) and acoustician Eiren Jacobson. Funding was provided by the U.S. Navy with additional support by NOAA's SWFSC.

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Table 1. Useable frequency range and dates used for each hydrophone array on the R/V *Derek M. Baylis* and M/V *Truth* during both legs of the SOCAL-BRS. On several occasions both arrays were used on the same day.

Array	***Hydrophone Type (# in array)***	***Useable Frequency Range***	***Dates used***
Tetrahedral	APC 10mm (6)	2-60 kHz	7/24 – 7/31
Oil 8	EDC 1” (2); Reson 4013 (2); APC 10mm (1)	2-40 kHz	7/23-7/24; 7/26-7/28; 7/30-8/4
Oil 10 + In-Line 10	APC 19mm (7); Reson 4013 (2)	2-60 kHz	9/11-9/12
Oil 10	APC 19mm (3); Reson 4013 (2)	2-60 kHz	9/13; 9/17-9/21; 9/23-9/24

Table 2. Summary of autonomous recorder deployments during the 2013 SOCAL-BRS.

Deployment Type	*Deployment Time/Date (GMT)*	*Total recorded hours*	*Location (Latitude)*	*(Longitude)*
C-POD	7/26/2013 13:14:04	34:57:30	33.3267	-118.5850
C-POD	7/31/2013 23:52:50	12:58:10	33.4204	-118.6078
C-POD	8/03/2013 00:02:15	14:00:55	33.4181	-118.6170
C-POD	8/03/2013 23:52:12	13:32:26	33.3742	-118.5878
C-POD	9/13/2013 02:00:40	16:34:58	33.4117	-118.6060
C-POD	9/18/2013 23:33:36	15:17:21	33.3806	-118.3009
DASBR	7/26/2013 13:12:58	34:58:04	33.3266	-118.5853
DASBR	7/31/2013 23:52:22	12:58:38	33.4205	-118.6077
DASBR	8/03/2013 00:01:32	14:01:08	33.4183	-118.6168
DASBR	8/03/2013 23:51:27	13:32:51	33.3744	-118.5874
DASBR	9/13/2013 02:00:17	16:34:27	33.4117	-118.6063
DASBR	9/18/2013 23:33:22	15:17:23	33.3806	-118.3010
DSG-Ocean	7/26/2013 13:13:37	34:57:40	33.3267	-118.5851
DSG-Ocean	7/29/2013 23:15:49	26:14:11	33.0727	-118.9749
DSG-Ocean	8/03/2013 00:30:01	12:41:44	33.4132	-118.5574
DSG-Ocean	9/12/2013 22:58:59	02:27:11	33.4825	-118.6940
DSG-Ocean	9/13/2013 02:04:06	17:12:42	33.4115	-118.6041
DSG-Ocean	9/14/2013 22:42:02	01:55:50	33.7658	-118.4906
DSG-Ocean	9/15/2013 20:11:00	03:47:44	33.8144	-118.4589
DSG-Ocean	9/16/2013 18:07:34	02:41:34	33.8244	-118.4704
DSG-Ocean	9/18/2013 13:30:00	01:00:00	33.3495	-118.3237
DSG-Ocean	9/18/2013 16:52:20	01:58:26	33.3487	-118.2301
DSG-Ocean	9/18/2013 23:31:11	15:35:36	33.3815	-118.3037
DSG-Ocean	9/19/2013 18:16:10	00:36:31	33.3694	-118.3326
DSG-Ocean	9/19/2013 19:28:05	01:38:31	33.3842	-118.3167
DSG-Ocean	9/23/2013 20:00:08	01:06:50	33.3545	-118.1730
XB	7/24/2013 12:56:36	647:03:24	33.7775	-119.4866

Table 3. Summary of acoustic and visual detections of marine mammals on the R/V *Derek M. Baylis* during Leg 1 of the SOCAL-BRS.

Species group / ***Subgroup*** / ***Common name***	***Scientific name(s)***	***Detections*** ***Acoustic (only)***	***Visual (only)***	***Acoustic & Visual***
Delphinids				
Small delphinids				
Long-beaked common dolphin	*Delphinus capensis*	0	0	9
Unidentified common dolphin	*Delphinus ssp.*	0	3	24
Unidentified delphinoid		20	9	3
Large delphinids				
Bottlenose dolphin	*Tursiops truncatus*	0	1	4
Risso's dolphin	*Grampus griseus*	6	6	11
Small whales				
Small beaked whales				
Cuvier's beaked whale	*Ziphius cavirostris*	6	1	4
Baird’s beaked whale*	*Berardius bairdii*	1	0	0
Large whales				
Blue whale	*Balaenoptera musculus*	0	3	0
Fin whale	*Balaenoptera physalus*	0	2	0
Sperm whale	*Physeter macrocephalus*	0	0	1
Unidentified Mysticete		0	1	0
Unidentified medium cetacean		0	1	0
Totals		**33**	**27**	**56**

*Baird’s beaked whale acoustic detection not confirmed by visual identification.

Table 4. Summary of acoustic detections of marine mammals on the M/V *Truth* during Leg 2 of the SOCAL-BRS.

Species group / ***Subgroup*** / ***Common name***	***Scientific name(s)***	***Detections*** ***Acoustic (only)***	***Acoustic & Visual***
Delphinids			
Small delphinids			
Short-beaked common dolphin	*Delphinus delphis*	0	2
Long-beaked common dolphin	*Delphinus capensis*	0	3
Unidentified common dolphin	*Delphinus ssp.*	5	21
Unidentified delphinoid		15	0
Large delphinids			
Bottlenose dolphin	*Tursiops truncatus*	1	14
Risso's dolphin	*Grampus griseus*	2	27
Large whales			
Sperm whale	*Physeter macrocephalus*	1	0
Totals		**24**	**67**

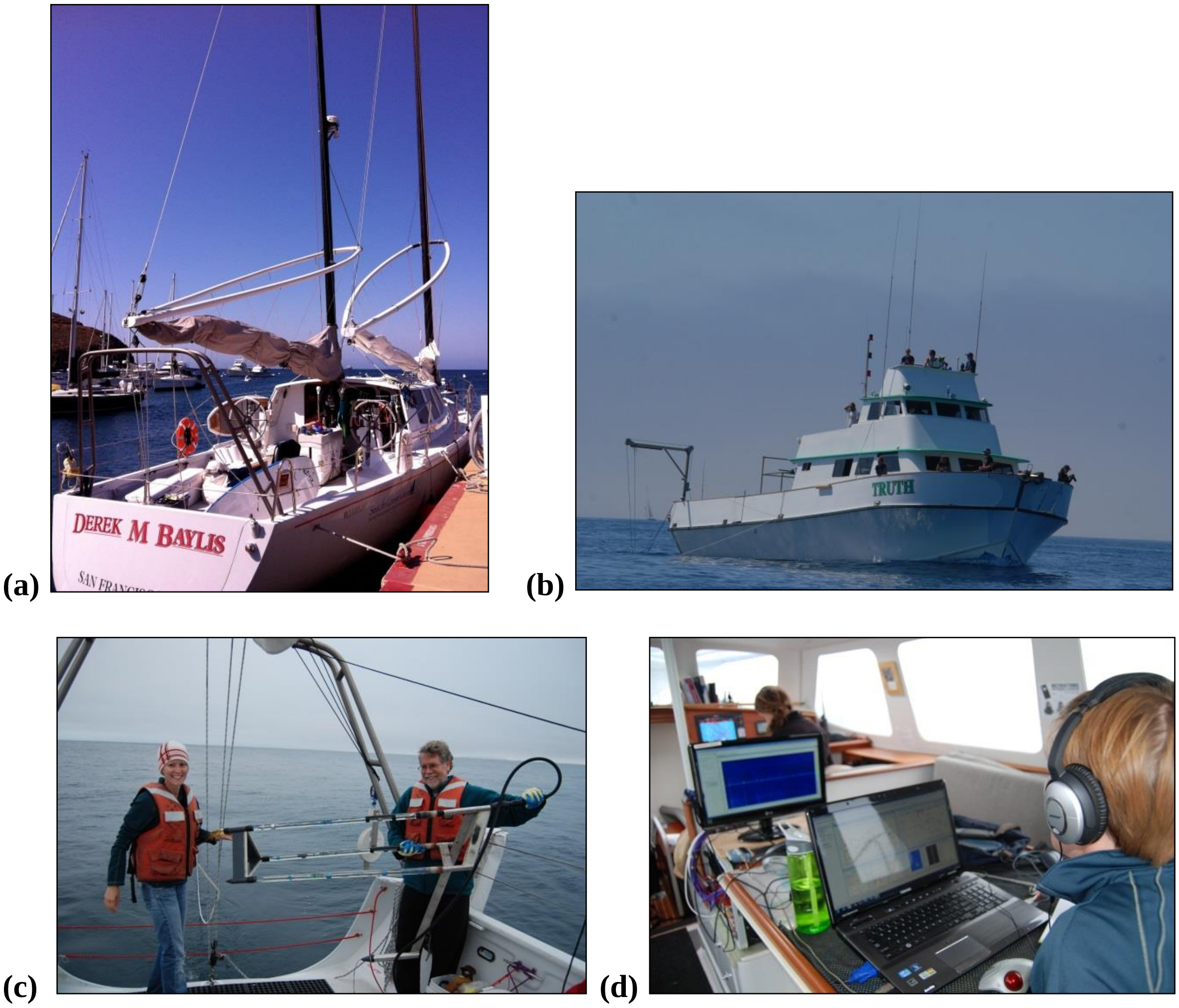

Figure 1. Passive acoustic monitoring (a) R/V *Derek M. Baylis*, (b) M/V *Truth* (c) towed tetrahedral acoustic array and (d) acoustic monitoring station. Photos by Jennifer L. Keating.

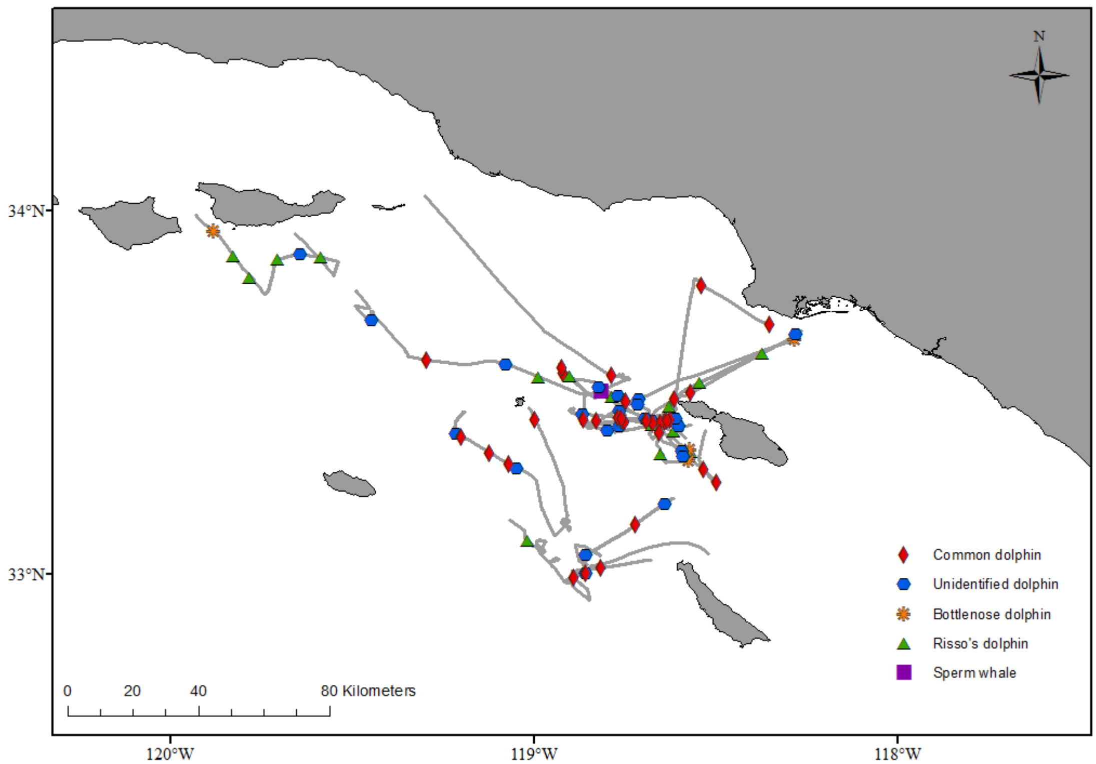

Figure 2. Acoustic detection of non-beaked whale odontocetes from the R/V *Derek M. Baylis* during Leg 1 of the 2013 SOCAL-BRS. Common dolphins are shown as red diamonds, unidentified dolphins are shown as blue polygons, bottlenose dolphins are shown as orange stars, Risso's dolphins are shown as green triangles, and sperm whales are shown as purple squares. Survey tracklines are shown as gray lines.

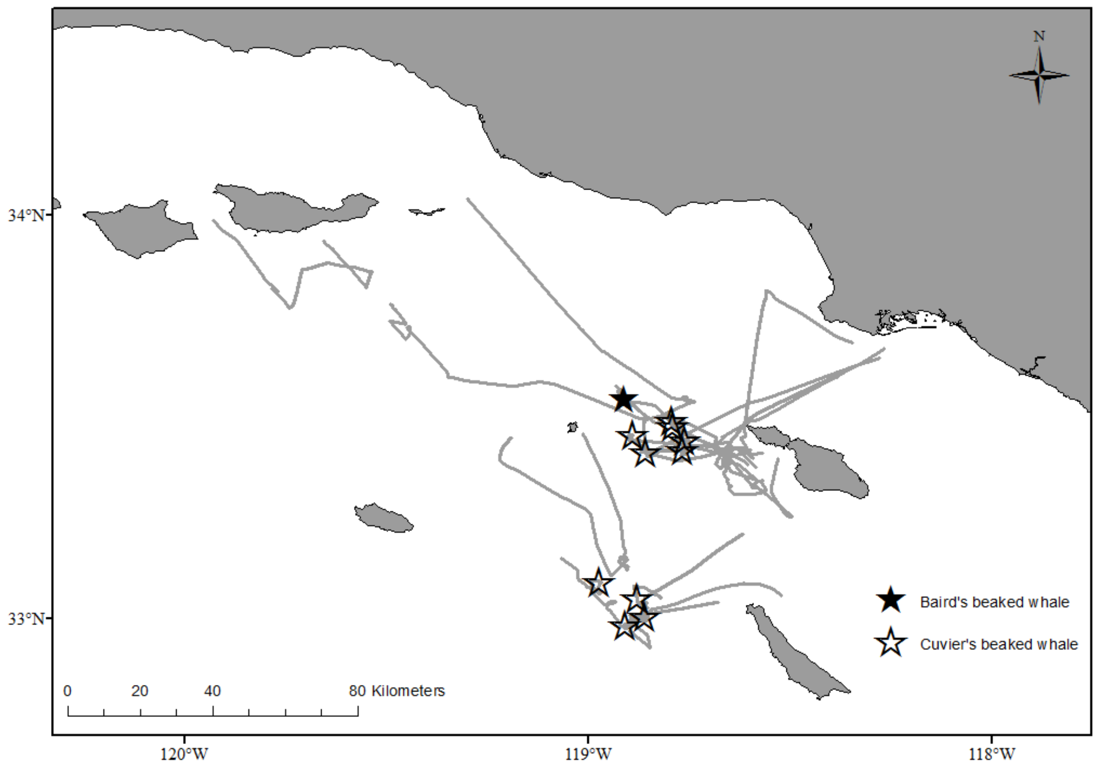

Figure 3. Acoustic detection of beaked whales (stars) from the R/V *Derek M. Baylis* during Leg 1 of the 2013 SOCAL-BRS. Survey tracklines are shown as gray lines.

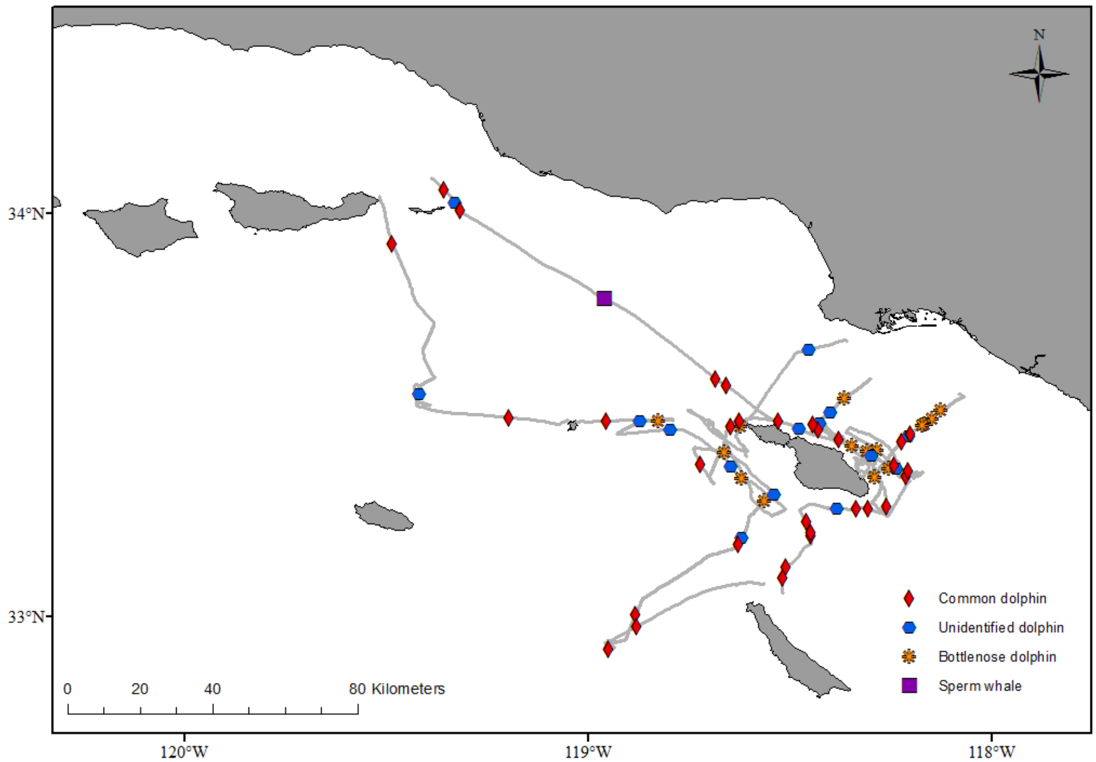

Figure 4. Acoustic detection of odontocetes, except Risso's dolphins, from the M/V *Truth* during Leg 2 of the 2013 SOCAL-BRS. Common dolphins are shown as red diamonds, unidentified dolphins are shown as blue polygons, bottlenose dolphins are shown as orange stars, and sperm whales are shown as purple squares. Survey tracklines are shown as gray lines.

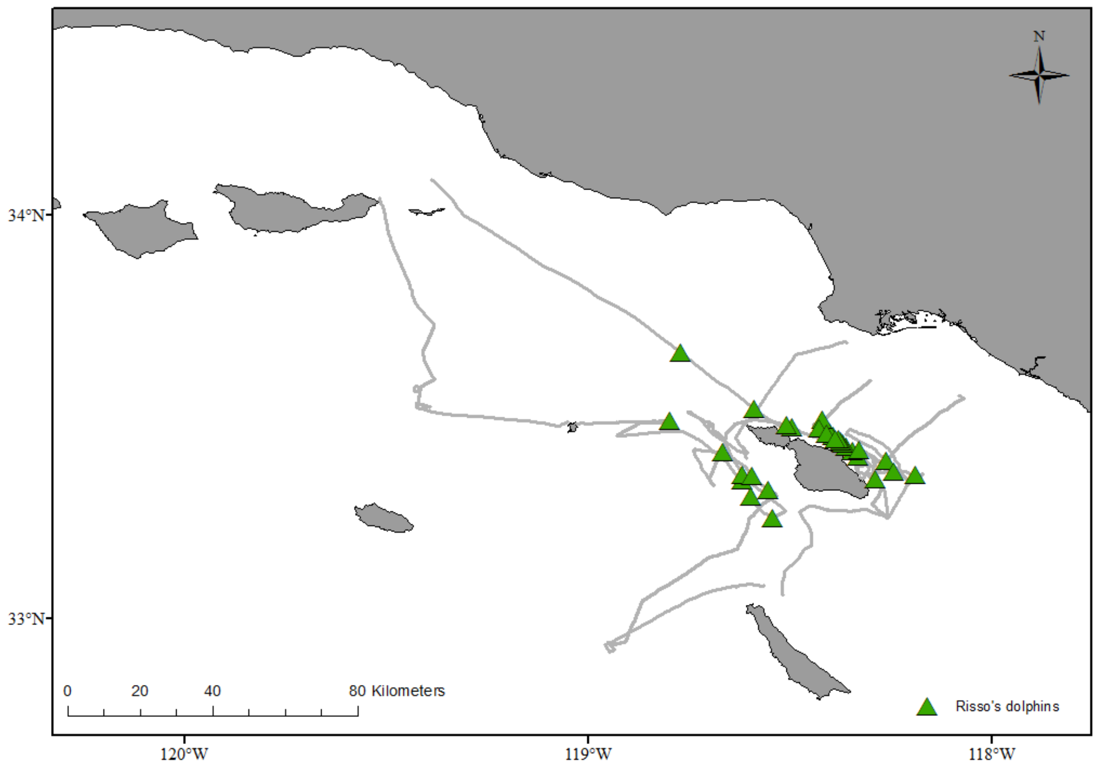

Figure 5. Acoustic detection of Risso's dolphins (green triangles) from the M/V *Truth* during Leg 2 of the 2013 SOCAL-BRS. Survey tracklines are shown as gray lines