Cascadia Research Collective
a non-profit research organization

Phone: (360) 943-7325
FAX: (360) 943-7026
Homepage: www.cascadiaresearch.org

FINAL REPORT

MARINE MAMMAL OBSERVATIONS AND MITIGATION ASSOCIATED WITH USGS SEISMIC SURVEYS IN THE SOUTHERN CALIFORNIA BIGHT IN 2000

Prepared for

U.S. Geological Survey
345 Middlefield Rd.
Menlo Park CA 94025

Prepared by

John Calambokidis
Todd Chandler

Cascadia Research
218½ W Fourth Ave.
Olympia, WA 98501

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INTRODUCTION

From 4 to 17 June 1999, the U.S. Geological Survey conducted seismic surveys in the coastal waters of the Pacific Ocean, between Los Angeles and San Diego, to investigate earthquake hazards. As a part of this project, Cascadia Research was contracted by the USGS to monitor marine mammals from the survey platform and provide mitigation on impacts on marine mammals by requesting shutdown of the sound sources when marine mammals were close to the operations.

This report summarizes the results of a marine mammal mitigation and monitoring program conducted in conjunction with these USGS surveys and adds information to similar work conducted by Cascadia Research in 1998 (Calambokidis et al 1998b). There were several modifications to observations and mitigation operations made for the 1999 survey from that in 1998: 1) Three observers were on board with two on duty during daylight observations, 2) the mitigation safety zone was extended from 200 meters to 250 meters for baleen and sperm whales, and 3) airgun operations during the night time hours were suspended.

BACKGROUND ON OVERALL PROJECT AND SOUND SOURCE DESCRIPTION

The following background on the overall project and sound source description was provided by USSGS:

The focus of this project is to identify the landslide and earthquake hazards, as well as related deformation processes, that have great potential to impact the social and economic well being of the inhabitants of the Southern California coastal region--the most heavily populated urban corridor along the U.S. Pacific margin. We are studying Pleistocene-Holocene sedimentation and deformation patterns and related seismicity and strain within the coastal zone and adjacent continental borderland basins. Our findings will help us evaluate the hazard potential for large, destructive earthquakes and identify how deformation is distributed in space and time between onshore and offshore regions. The results of this project will contribute to decisions involving land use, hazard zonation, and building codes in the area.

The active field program for the project focuses on those areas with the greatest impact potential on the Southern California populace:

1) The coastal strip (coastal zone and continental shelf) between Los Angeles and San Diego, where much of the hazard appears to be associated with strike-slip or oblique-slip faults;
2) Active faults within the Santa Monica, San Pedro, and San Diego Trough basins, where more extensive sedimentation has left a greater stratigraphic record;
3) The offshore extension into the Santa Barbara Channel of the fold and thrust belt;
4) The boundary (Channel Islands region) between the inner California Borderland (strike-slip dominated deformation) and the Santa Barbara Channel (thrust and fold deformation).

Tracklines were planned at a 2 km spacing aligned perpendicular to the shelf break and basin slope and on an "orthogonal" set aligned to intercept major structural features that are oblique to the trend of the basin slope and shelf edge. For the FY 1999, only one set of

tracklines was attempted because of time limitation on hours of operation. As a result, generally only every other line was run, i.e., the grid was 4 km spacing with only one set of the planned grid over most of the area.

The FY 1999 field program was conducted using a leased vessel, the 156-ft-long M/V OCEAN OLYMPIC, owned and operated by F/V NORTH WIND INC. Two sound transmissions were used:

Huntec: A high-resolution Huntec DTS boomer system, towed between 6 m and 160 m below the sea surface (depending upon the water depth), was used to image the upper few tens of milliseconds of strata with a resolution of better than 0.5 ms (0.4 m). Power output was 350 Joules (540) with a firing rate that was also dependent on water depth, ranging from 0.4 sec over the shelf and upper basin slopes to 1.3 sec over the shelf and upper basin slopes to 1.25 sec over the deeper parts of the basins. Returning signals were received with a 7.6 m long 25-element hydrophone array. Signals were filtered at 700-8000 Hz and recorded at a 0.25 sec sweep. The data were recorded both on paper using an EPC recorder and on magneto-optical disc.

Multichannel seismic-reflection system (MCS): The sound source used during this years survey was a 35/35 in^3 double-chamber GI gun firing every 12 seconds at a pressure of about 3000 psi. A Sureshot system was used to fire the gun in "harmonic mode" wherein the second chamber is delayed relative to the initial trigger pulse in order to achieve the cleanest signal by minimizing the bubble pulse. The GI gun was towed 12 meters behind the vessel and suspended from a float to maintain a depth of about 1 meter.

The streamer used for the mcs operation was a 24-channel ITI streamer with 10-m-long groups and 3 phones per group.

OBJECTIVES

The objectives of the marine mammal study were as follows:

1. Mitigate impacts on marine mammals by monitoring the presence of these species from the survey ship and requesting shut-down of the airgun array when marine mammals were seen within specified safety zones representing distances close enough to potentially cause physically injury.

2. Document the number of animals of each species present in the vicinity of sound transmissions.

3. Evaluate the reactions of marine mammals to the sound transmissions at different distances from the airgun array.

4. Conduct limited tests of night vision equipment.

METHODS

General Approach

The research effort consisted of observations made directly from the seismic vessel (*Ocean Olympic*) to provide mitigation, document marine mammals exposed to the airgun during daylight hours, and monitor reactions of marine mammals close to the seismic survey vessel. Three observers were placed on board the vessel and observations were conducted from the bridge deck that put the observers eye level at 7.8 m above the water. This external platform provided good mobility and a clear view from the front, sides and rear of the vessel. The observation platform was near the front of the vessel 7.2-m behind the bow and 47 m from the stern of the vessel.

Observations were conducted from the seismic vessel (*Ocean Olympic*), during a short transit period (between June 4 and 5) and in the daylight when seismic operations were underway. While the seismic operations were underway observations began within a half hour of sunrise, when lighting conditions allowed for the sightings to be made within the mitigation zones and ended within an half an hour after sundown, when lighting conditions became too dark for sightings to made within the mitigation zone. During the daylight observation periods, two observers stood watch, one on the port and the other the starboard. The third observer would rotate in every two hours. Generally, each observer worked shifts of four hours on and two hours off (averaging about 11 hour per day). Observers used *Tasco 7x50* binoculars with internal compasses and reticles to record the horizontal and vertical angle to sightings.

Data on survey effort and sightings were recorded on a datasheet recording information to track survey effort which includes observers on duty and weather conditions (Beaufort sea state, wind speed, cloud cover, swell height, precipitation, visibility, etc.). For each sighting the time, bearing and reticle reading to sighting, species, group size, surface behavior and orientation were recorded.

Distances to sightings were calculated using the vertical angle to the animal (based on either the reticle reading through the binoculars or a hand help clinometer for close sightings) and the known elevation above the water. This was then used to evaluate whether a sighting was within the mitigation safety zones.

Mitigation safety zones

Two safety zones were used for this project. These were:

1. For pinnipeds and odontocetes (all toothed cetaceans except sperm whales) seismic operations would be shut down when an animal was seen close to a distance of 100 m or less.

2. For mysticetes (baleen whales) and sperm whales, the safety zone was 250 m.

To allow a quick determination of status, safety zones were calculated in three arcs around the ship and the safety distance was applied using the closest part of the ship or array. Three different cut-off distances (based on distance and angle from the observers) were calculated for off the bow (60 degrees to either side of the bow), to either side of the vessel (from 60 to 120 degrees off the bow and off the stern (120 to 180 degrees off the bow).

Observers were instructed to call for a shut-down when a marine mammal was seen inside the safety zone or close enough to the safety zone that given measurement-error, it could be within the safety zone. Shut-down was also considered when animals were ahead of the vessel path outside the safety zone, but it appeared likely that the direction of travel of the vessel would result in the marine mammal being within the safety zone shortly. Marine mammals were tracked until they were outside the safety zone at which time seismic operations resumed.

For effective mitigation, the observers needed to know very quickly whether a sighting was within the safety zone. We used a polaris (angle board) for the observers to estimate the angle to the sighting. The cut-off vertical angle, which represented each of the safety zones, was also written on the polaris, allowing quick determination of the proximity of a sighting to the safety zone.

Night Observations

A total of 6 hour and 36 minutes, over the span of seven nights, was devoted to night observations. Two different sets of night vision viewers supplied by USGS were tested (ITT night vision binoculars model 200/210 and model 250/260). Night observations were conducted by one observer and took place from the bridge, bridge wings and bridge deck. Observations were limited toward the front of ship to 95 degrees either side of the bow, as deck lights on the stern of the vessel created light conditions (too bright) that were not conducive for viewing with the night vision viewers. Observations were conducted in weather conditions that ranged from 0% cloud cover to 100%, and in Beaufort sea states ranging from 1-5. Two sightings of common dolphin, *Delphinus delphis*, were recorded during night observations, both occurring on the evening of 6 June 1999. The first sighting was a “re-sight” of animals originally observed during daylight observation operations. Both observations were made by “naked-eye”, and as the dolphins approached the ship to ride the bow waves and wake waves made by the vessel. No sighting of marine mammals were made with the aid of either night scope.

RESULTS AND DISCUSSION

Marine mammal mitigation – Shut-downs

Shut-down of the airgun was called for in 21 instances during the daylight observations (Table 1). In all shut-down cases both the airgun and the Huntec were in firing operation. Seventeen of the shut-downs were for common dolphin (in seven of these shut-downs the dolphins approached the ship to bow ride) and in one of the shut-downs the dolphins where associated with a California sea lion. The other shut-downs requested were: one for a California sea lion, one for an unidentified pinniped, one for a large baleen whale (sei whale or fin whale), and one for a group of Pacific white-sided dolphin (which approached the ship to bow ride). Shut-downs lasted anywhere from less than one minute to 13 minutes. Twelve of the shutdowns were called when the animal was just outside the safety zones but appeared likely to be within the safety zone shortly, and nine shut-downs were called when the animals were seen already within the safety zones.

Marine mammal sightings

There were a total of 181 sightings (not including re-sightings), comprised of 13,486 marine mammal during observation operations (Table 2) and more than half (60%) of the sightings were made while the airgun and Huntec were in operation (Table 3). Some of these groups were seen more than one time, and account for 156 re-sightings. Nine species of marine mammals made up these sightings. Humpback whales and Dall's porpoise were seen only in the transit area (from roughly San Francisco to just north of Los Angeles – during which time no seismic equipment was deployed). Within the survey area common dolphin, blue whales, and California sea lions were the most frequently observed. Other large whale species included a number of unidentified whales, one of, which was likely to be either a sei or fin whale. Other small cetaceans included Risso's dolphin, Pacific white-sided dolphin, and one sighting of Bottlenose dolphin. Sightings of unidentified dolphin were likely to be either common dolphin or Pacific white-sided dolphin. Beside California sea lions, no other pinnipeds were positively identified.

Orientation and behavior of marine mammals in relation to firing status of seismic equipment

Orientation (Table 4) – John! (now Jen)

Marine mammals were observed exhibiting a variety of behaviors (Table 5). The most common behaviors that were observed were classified as slow or fast travel. Other common behaviors were milling, which can indicate feeding activity, porposing (California sea lions), and bow riding (common dolphins, Pacific white-sided dolphin, and Dall's porpoise). Less common behaviors included slow rolling, breaching, fluke diving, medium travel, and hauled, splashing and vertical sinks (the last three behaviors describe those associated only with pinnipeds). It is

not possible to determine if any of these activities could have been related to the seismic operations.

Night Observations

The objective of the night observations was to test the utility of night vision viewers as a tool for observing for and detecting marine mammals at night. Of the two sets of viewers used the Viewer 200/210, was favored for its consistent clarity and focus, while the Viewer 250/260 was highly variable in its over all performance, was too grainy, and did not hold it's focus. While the Viewer 200/210 provided some assistance in night observations it was limited by the following factors:

- Distance Detection – There are no methods for determining distance (as with reticule binoculars) while observing through the scope, and observers felt that confidence in estimating distance in the dark and while observing through the viewers did not extend beyond 100 meters.

- Field of View - The field of view is limiting, allowing roughly, only a span of 40 degrees to be observed at a time.

- Ambient light conditions - Ambient light conditions may have an affect on sighting ability. Conditions seem to improve when some ambient light is present, as with water lit by a cityscape or moon light. In conditions of complete darkness/ cloud cover, the possibility of detection seems lower, as not even the horizon is visible.

- Lights from the Observation Vessel - Deck lights on the stern of the ship were too bright, and made observation around the sound source itself impossible.

- Sea State - Observation of the dolphins made with the viewers, on 6 June 1999, were in Beaufort 3 conditions. The animals were only distinguishable from white caps when within roughly 6 meters of the bow.

- Physical Constraints - The viewers where physically constraining, allowing the observer to safely move around at a slow speeds, and use of the goggle for an hour produced eye strain for some of the observers.

DISCUSSION AND CONCLUSSIONS

Shut-downs were more common in 1999 compared to 1998. Most of the shut-downs were from common dolphins a species that was sighted more times in 1999 compared to the 1998 surveys. Surveys were conducted slightly earlier in the year in 1999 and also covered a slightly different area. Either of these or the annual differences in oceanographic conditions could have been responsible for the higher number of sightings of this species and resultant higher shut-downs. This species often approaches boat to bow ride which caused the high number of shut-downs when this species was encountered.

There were also larger numbers of baleen whales encountered in 1999 compared to 1998. Some of these sightings, including those of humpback whales were primarily made while the vessel was in transit to the study area prior to airgun operations. Sightings of blue whales were still far more common within the study area during airgun operations in 1999 compared to 1998; 15 sightings were made in 1999 during operations compared to only 3 in 1999 (includes possible fin whales). Again the timing of the surveys or inter-annual oceanographic changes could have been responsible for the differences.

No sightings were made with the aid of the night vision viewers, and therefore the utility of the night vision viewers as a tool for detecting marine mammals at night is Difficult to determine. This assessment of night observations operations has revealed that for night observations to be marginally effective while using the night vision viewers requires:

- Methods for detection of distance would need to be established
- Viewing conditions would have to have some level of ambient light
- Deck lights on the stern of the ship would have to be dimmed or extinguished
- Sea State conditions would have to be at a Beaufort three or lower
- To compensate for the 40 degree field of view, at least three observers per shift would be needed.
- Observation shifts no longer than two hours to allow for relief of eye strain, or until the observers eyes adjust to such sighting conditions.

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Table 1. Summary of shut-downs called for based on sightings of marine mammals during 2000 surveys.

Date	Firing	Dy/Nt.	Time			Tot #	Species	Sit#	Obs	Meth	Comments
			Sight	Sht-dn	Resume						
08-Jun-00	HT	D	0902	0902	0950	1	Common dolphin	7	JRV	E	Fast traveling
10-Jun-00	GP	N	0306	0306	0308	6	Botthenose dolphin	14	JRV	N	Slow traveling
10-Jun-00	N	N	0440	0440	0446	1	Risso's dolphin?	15	ABD	N	Slow traveling
10-Jun-00	GP	D	1310	1315	1322	60	Common dolphin	21	ABD	B	Milling then bowriding
10-Jun-00	GP	D	1645	1645	1654	1	California sea lion	23	TEC	E	Fast traveling, swam under boat
11-Jun-00	GP/SD/HT	D	1524	1534	1600	50	Common dolphin	36	TEC	B	Fast traveling
12-Jun-00	GP	D	1515	1515	1530	1	Blue whale	49	ABD	B	Slow traveling, outside zone
13-Jun-00	HT	D	1631	1632	1639	12	Common dolphin	54	ABD	E	Bow riding
13-Jun-00	GP	N	2240	2240	2252	30	Common dolphin	57	LSB	E	Fast traveling
14-Jun-00	GP	N	0034	0034	0129	12	Common dolphin	58	DKE	N	Fast traveling
14-Jun-00	GP	D	2003	2003	2009	30	Common dolphin	65	TEC	E	Slow traveling then accelerated
15-Jun-00	HT	N	0500	0500	0506	12	Common dolphin	66	LSB	N	Bow riding
15-Jun-00	GP	D	0558	0558	0603	12	Common dolphin	71	LSB	E	Bow riding
15-Jun-00	GP	D	0631	0634	0636	75	Common dolphin	74	ABD	B	Fast traveling, part of group approaches boat
15-Jun-00	HT	D	0912	0914	0917	28	Common dolphin	79	ABD	E	Slow traveling
15-Jun-00	HT	D	1035	1036	1040	12	Risso's dolphin	81	LSB	E	Slow traveling
15-Jun-00	GP	N	2328	2328	2335	3	Unidentified dolphin	83	DKE	N	Fast traveling
16-Jun-00	GP	N	0025	0025	0032	5	Common dolphin	84	TEC	N	Slow traveling
16-Jun-00	SP	N	2152	2152	2159	1	Common dolphin	89	JRV	N	Slow traveling
17-Jun-00	HT	D	2025	2025	2028	12	Common dolphin	94	JRV	E	Fast traveling
17-Jun-00	HT	N	2118	2118	2121	2	Common dolphin	95	JRV	N	Bow riding
17-Jun-00	HT	N	2146	2146	2155	40	Common dolphin	96	JRV	N	Fast traveling
18-Jun-00	HT	N	0452	0452	0500	6	Botthenose dolphin?	97	DKE	N	Slow traveling
18-Jun-00	HT	D	0935	0936	0939	10	Botthenose and Risso's dolphin	109B	LSB	E	Fast traveling
18-Jun-00	SP	D	1929	1935	1954	20	Common dolphin	119	ABD	E	Milling
19-Jun-00	HT	N	2234	2234	2239	2	Common dolphin	130	TEC	N	Slow traveling
20-Jun-00	HT	D	0647	0650	0653	120	Common dolphin	134	JRV	B	Fast traveling
20-Jun-00	HT/SD	N	2331	2331	2335	1	Common dolphin	141	TEC	E	Slow traveling
20-Jun-00	HT/SD	N	2357	2357	0002	4	Common dolphin	142	TEC/L	E	Slow traveling
21-Jun-00	HT/SD	N	0014	0014	0019	3	Common dolphin	143	JRV	N	Bow riding
23-Jun-00	HT	N	0121	0121	0123	2	Botthenose dolphin	166	JRV	E	Fast traveling
24-Jun-00	SP	D	0613	0617	0650	1	California sea lion	184	TEC	E	Slow traveling
25-Jun-00	HT	N	2303	2303	2308	3	Common dolphin	204	JRV	E	Bow riding
27-Jun-00	HT	N	0456	0458	0503	20	Common dolphin	219	JRV	E	Slow traveling
27-Jun-00	HT	D	0605	0605	0606	1	California sea lion	222	ABD	E	Slow traveling
27-Jun-00	HT	D	0956	0957	1016	18	Common dolphin	228	TEC	E	Slow traveling, testing equip delayed restart
27-Jun-00	SP	D	1124	1130	1134	60	Common dolphin	234	DKE	B	Slow traveling
27-Jun-00	SP	D	1143	1147	1154	65	Common dolphin	235	DKE	E	Fast traveling
27-Jun-00	N	D	1150	1159	1205	1	Common dolphin	236	JRV	E	Slow traveling
27-Jun-00	HT	D	1220	1220	1222	700	Common dolphin	239	LSB	E	Fast traveling

Table 2. Summary of sightings and resightings by species in 2000. Resightings represent groups seen more than one time. Does not include sightings outside study area during transit to and from region.

	Sighting		Resighting	
Species	**# of sightings**	**# of Animals**	**# of sightings**	**# of Animals**
Large whales				
Blue whale	5	5	4	4
Fin whale	1	1	2	2
Humpback whale	1	2		
Large Balaenopterid	1	1	2	2
Minke whale	2	3	2	4
Unidentified whale	2	2		
Small cetaceans				
Common dolphin (short & long-beaked)	74	3764	20	2047
Risso's dolphin	14	120	4	35
Dall's porpoise	2	2		
Bottlenose dolphin	10	82	4	41
Unidentified dolphin	31	627	1	55
Pinnipeds				
California sea lion	87	171	4	10
Elephant seal	1	1		
Harbor seal	7	8		
Unidentified pinniped	3	3		
Grand Total	241	4792	43	2200

Table 2. Summary of sightings and resightings by species in 2000. Resightings represent groups seen more than one time. Does not include sightings outside study area during transit to and from region.

	Geopulse		Huntec		None		Sparker		Uniboom		Geopulse/Huntec	
Species	**# Sit**	**# Anim**	**# Sit**	**# Anim**	**# Sit**	**# Anim**	**# Sit**	**# Anim**	**# Sit**	**# Anim**	**# Sit**	**# Anim**
Large whales												
Blue whale	3	3	2	2								
Fin whale	1	1										
Humpback whale					1	2						
Large Balaenopterid			1	1								
Minke whale			2	3								
Unidentified whale			1	1			1	1				
Small cetaceans												
Common dolphin (short & long-beaked)	18	782	41	1735	6	795	4	146	0	0	5	306
Risso's dolphin	2	18	9	80	1	1	2	21				
Dall's porpoise			2	2								
Bottlenose dolphin	5	36	3	14			2	32				
Unidentified dolphin	7	116	18	371	1	5	5	135				
Pinnipeds												
California sea lion	15	28	23	28	18	32	30	76	1	7		
Elephant seal			1	1								
Harbor seal	5	6	2	2								
Unidentified pinniped	1	1	1	1			1	1				
Total Sightings	57	991	106	2241	27	835	45	412	1	7	5	306
Summary of effort												
Hours	154		163		69		69		2		3	
nmi	485		775		484		227		6		11	