

FINAL REPORT

**MARINE MAMMAL OBSERVATIONS AND MITIGATION ASSOCIATED WITH
USGS SEISMIC SURVEYS IN THE SOUTHERN CALIFORNIA BIGHT IN 1999**

Prepared for

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INTRODUCTION

From 6 to 17 June 1999 (4 to 5 June were transit days), the U.S. Geological Survey conducted seismic-reflection 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 in³ 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 physical 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 survey 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-reflection 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 fishing vessel (*Ocean Olympic*), during a short transit period (between June 4 and 5) and in the daylight when seismic-reflection operations were underway. While the seismic-reflection 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 be 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 held 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-reflection 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 hours 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 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 Hunttec 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 were 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 mammals encountered during observation operations (Table 2) and more than half (60%) of the sightings were made while the airgun and Hunttec 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-reflection 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

Marine mammals were observed moving in all directions in relation to the heading of the vessel (Table 4). Sightings of animals seen while both the airgun and Hunttec were firing tended to be slightly more towards (22%) than away (11%) and the re-sightings slightly more away (23%) than towards (15%). A large portion of the animals observed moving towards the ship, during these times, were common dolphin which are well known for approaching ships to ride the bow wake, and which may account for the higher number of animals seen moving toward the ship when initially sighted. Some of these groups did approach the ship to bow ride and when ceased bow riding were re-sighted moving away from the ship which may account for the higher number of animals observed moving away when re-sighted. Overall there were no major

differences in the movements observed in relation to firing status of the airgun and Hunttec or when the equipment was not firing at all. Further, it is not possible to determine if any of the observed movements could be attributed to marine mammals reacting to the seismic equipment.

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, porpoising (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-reflection 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 its 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 CONCLUSIONS

Shut-downs were more common in 1999 compared to 1998. Most of the shut-downs were related to common dolphins. This species was sighted more times in 1999 than during 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 the boat to bow ride thus causing 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.

Marine mammal movements and behaviors observed during the seismic-reflection operations, revealed no apparent patterns of avoidance and none could be interpreted as harassment.

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. Shut-down requests due to marine mammal occurrences, during the Hunttec and Airgun operations. Distance is based on approximate distance of marine mammals from the observer at the time the shut down was requested. Behaviors are based on the those observed at and during the time of the requested shut-down.

Date	Time	Resume	Species	Distance	Behavours	Comments
06/06/99	13:17:00	13:20:00	common dolphin, California sea lion	3 meters	Slow travel	
06/06/99	16:53:00	16:55:00	common dolphin	106 meters	Milling	
06/06/99	20:33:00		common dolphin	< 100 meters	Fast Travel, Bow riding	Too dark to continue obs.
06/07/99	6:34:00	6:39:00	common dolphin	106 meters	Fast Travel, Bow riding	
06/07/99	8:41:00	8:41:00	California sea lion	< 100 meters		
06/07/99	9:48:00	9:54:00	common dolphin	2 meters	Slow travel, Milling	
06/08/99	16:05:00	16:18:00	common dolphin	37 meters	Bow riding	
06/09/99	14:18:00	14:20:00	common dolphin	109 meters	Bow riding	
06/10/99	17:23:00	17:24:00	common dolphin	109 meters	Fast Travel	
06/13/99	8:23:00	8:25:00	common dolphin	109 meters	Slow travel, Milling	
06/14/99	10:35:00	10:38:00	common dolphin	109 meters	Bow riding	
06/14/99	12:14:00	12:16:00	common dolphin	< 100 meters	Bow riding	
06/14/99	17:17:00	17:22:00	common dolphin	109 meters	Slow travel, Milling	
06/14/99	20:14:00	20:15:00	common dolphin	97 meters	Slow travel	
06/15/99	6:23:00	7:02:00	common dolphin	111 meters	Slow travel	Resume time includes, shut down for trackline change.
06/15/99	9:23:00	9:34:00	Pacific white-sided dolphin	101 meters	Slow travel, Bow riding, Wake riding	
06/15/99	13:47:00	13:50:00	common dolphin	101 meters	Fast Travel, Bow riding	
06/15/99	13:55:00	13:59:00	common dolphin	111 meters	Fast Travel, Wake riding	
06/15/99	14:51:00	14:53:00	unidentified pinniped	19 meters		
06/15/99	18:35:00	18:40:00	unidentified baleen whale (fin or sei)	158 meters	Slow travel	
06/16/99	10:58:00	11:01:00	common dolphin	109 meters	Slow travel, Milling	

Table 2. Summary of sightings and resightings by species. Resightings represent groups seen more than one time.

Species	Sighting		Resighting	
	# of sightings	# of Animals	# of sightings	# of Animals
Large whales				
Blue whale	27	32	30	36
Humpback whale	24	39	10	18
Large Balaenopterid (sei or fin)	1	1	1	1
Unidentified whale	12	12	2	2
Small cetaceans				
Common dolphin	66	11,569	87	21,116
Risso's dolphin	4	27	7	58
Pacific white-sided dolphin	3	118	3	98
Dall's porpoise	4	25		
Bottlenose dolphin	1	2		
Unidentified dolphin	15	1,637	9	950
Pinnipeds				
California sea lion	21	21	6	6
Unidentified pinniped	2	2	1	1
Unidentified Oratriid (California sea lion or Northern fur seal)	1	1		
Grand Total	181	13,486	156	22,286

Table 3. Sightings and total number of animals seen by operational status of airgun and Hunttec.

Species	Airgun and Hunttec		Hunttec only		None Firing		Total	
	# of Sight.	# of Animals	# of Sight.	# of Animals	# of Sight.	# of Animals	# of Sight.	# of Animals
Large whales								
Blue whale	15	17			12	15	27	32
Humpback whale					24	39	24	39
Large Balaenopterid (sei or fin)	1	1					1	1
Unidentified whale	5	5			7	7	12	12
							0	0
							0	0
Small cetaceans								
Common dolphin	54	9,443	3	30	9	2,096	66	11,569
Risso's dolphin	3	25			1	2	4	27
Pacific white-sided dolphin	2	53			1	65	3	118
Dall's porpoise					4	25	4	25
Bottlenose dolphin	1	2					1	2
Unidentified dolphin	13	1,367	1	30	1	240	15	1,637
							0	0
							0	0
Pinnipeds								
California sea lion	12	12			9	9	21	21
Unidentified pinniped	1	1			1	1	2	2
Unidentified Oratriid (California sea lion or Northern fur seal)	1	1					1	1
Grand Total	108	10,927	4	60	69	2,499	181	13,486

Table 4. Percent of total observed headings of marine mammals by sightings and resightings and by sound source(s) firing status. Headings are relative to the direction of the survey vessel.

Heading	Firing Status				Total		Total (n)
	Airgun and Hunttec		Hunttec only and None firing		# of Sight.	# of Resight.	
	# of Sight.	# of Resight.	# of Sight.	# of Resight.	# of Sight.	# of Resight.	
Away	11%	24%	17%	15%	43%	57%	47
Left	36%	30%	17%	33%	54%	46%	83
Right	32%	31%	36%	22%	59%	41%	87
Toward	22%	15%	30%	30%	62%	38%	61
Total (n)	101	97	53	27	154	124	278

Table 5. Primary behaviors of marine mammals observed during sightings and resightings relative to firing status of sound source(s).

Behavior	Firing Status				Total for both
	Airgun and Huntec		Huntec only and None firing		
	# of Sightings	# of Resightings	# of Sightings	# of Resightings	
Slow travel	51	55	36	28	170
Fast travel	32	36	11	2	81
Milling	7	13	2	3	25
Porpoising	3		3		6
Bow riding			4	8	12
Slow roll	3				3
Breaching	1		1		2
Medium travel	1	1			2
Fluke diving	1				1
Hauled	1				1
Splashing			1		1
Vertical sink			1		1
Total	100	105	59	41	305