

## FINAL TECHNICAL REPORT

### Underwater Behavior of Blue Whales Using a Suction-cup Attached CRITTERCAM

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Grant Number: N00014-00-1-0942  
<http://www.cascadiaresearch.org>

November 2002

## **ABSTRACT**

We deployed an instrument package developed by National Geographic (CRITTERCAM) on blue whales at three locations and time periods to examine their underwater behavior. Deployments were conducted in Monterey Bay, southern California Bight, and Sea of Cortez, Mexico. In total, 17 deployments were made, with 8 deployments and recoveries of 15 min to over 6 h. We have developed more effective approaches resulting in an increased success rate in attaching tags, and improved the performance of the Crittercams themselves. Deployments have revealed that: 1) whales were feeding by conducting multiple upward lunges into prey, 2) whales were coming into the krill layer from below and then inverting, 3) lunges brought the whales to near stand-still within dense layers of krill, 4) blue whales were diving deeper (300 m) than had previously been reported, 5) most animals were not vocalizing during feeding, and 6) there did not appear to be close spacing or coordination between pairs of whales.

## **INTRODUCTION**

The overall long-term goal of the research was to examine the underwater behavior including the vocal behavior of blue whales. While increased attention has been paid to the remote monitoring of blue whales through their vocalizations, relatively little is known about vocal behavior of individual animals. We sought to monitor a variety of parameters including visual behavior, vocalizations, and dive patterns in the context of known-gender identified animals.

We had the following objectives:

1. Increase sample size of integrated visual, acoustic, dive and feeding behavior of blue whales
2. Collect related data; history, sex, and size using photo-ID, skin sampling, and photogrammetry
3. Examine differences in behavior among three different habitats and seasons
4. Bring together inter-disciplinary team to collaborate in the integration of the data components
5. Test and improve methods for approaching and deploying instruments on blue whales that will be valuable for the deployment of other instrument packages being developed.

We conducted deployments of the instrument package CRITTERCAM developed by National Geographic on blue whales at three locations and time periods to examine their underwater behavior.

## **METHODS**

Underwater video, sound, depth and temperature were recorded using a modified instrument package termed CRITTERCAM (Marshall 1998). The instrument package was developed by National Geographic and has been used on a number of marine species. The modified, Hi-8 recording camera with datalogger was housed in a 31 cm long x 10 cm diameter cylinder outfitted with a ring of high output red LEDs and hydrophone (Figure 1). The CRITTERCAM was attached to the whale with a low profile silicon suction cup (22 cm diameter) with the aid of a remote vacuum pump. Field monitoring in addition to attachment of the CRITTERCAM included photographic identification of individual animals (to be linked with sighting histories from archived data), collection of skin from biopsy or sloughed skin (to allow gender determination), and photogrammetry (to estimate size). The instrument package and field data provides the following:

- Visual data showing the animals' position, swimming rate and underwater action from the Hi-8 video recorder

- Acoustic data from the onboard hydrophone recorded to the Hi-8 track
- Dive data from the pressure sensor
- Temperature data
- Photo-ID to allow determination of sighting history and other parameters for animal
- Gender from sloughed skin and possibly biopsy
- General size of the animal from subjective observation and fluke size based on new photogrammetry technique using laser range-finder



**Figure 1. CRITTERCAM package on the back of a blue whale in the Sea of Cortez in March 2001.**

Deployments under this project were conducted in three regions and time periods (summaries of the deployments by regions are included under Results below):

1. Monterey Bay in central/northern California from 12 to 19 September 2000
2. Sea of Cortez, Mexico from 26 February to 6 March 2001
3. Southern California Bight from 14 to 26 July 2001

## RESULTS

Through the end of 2001, 17 deployments have been conducted on blue whales, with 8 of these successfully recovered instruments that stayed on the whale from 15 minutes to over 6 hours (including a single deployment completed prior to ONR funding).

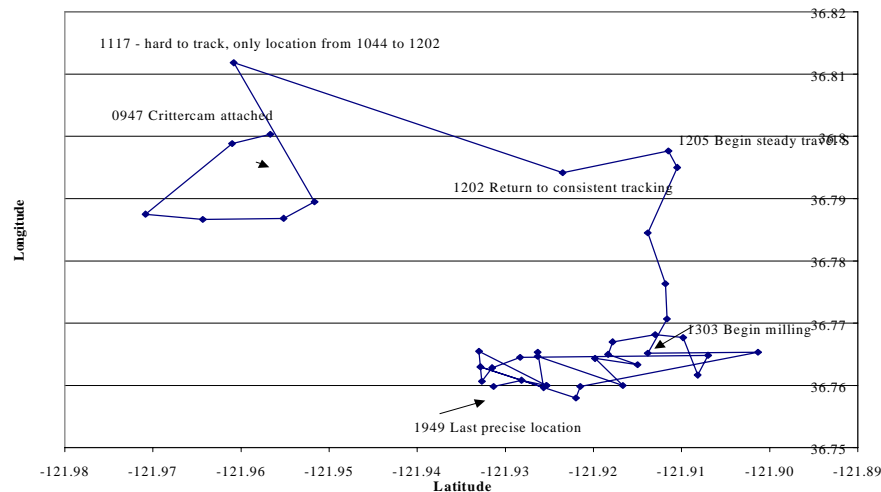
Table 1. Summary of effort deploying Crittercams on blue whales

Location	Start date	End date	Approaches	Contact	Attach			
					#	#	%	#
Bodega Bay, CA	19-Sep-99	21-Sep-99	10*	7	1	<10%	1	1
Monterey Bay, CA	12-Sep-00	19-Sep-00	6	3	1	17%	1	1
Sea of Cortez, MX	26-Feb-01	6-Mar-01	16	7	5	31%	4	1
S Cal. Bight, CA	14-Jul-01	26-Jul-01	26	18	12	46%	11	5
Total			58	35	19	33%	17	8

\* Minimum

A summary of field effort by region is included below:

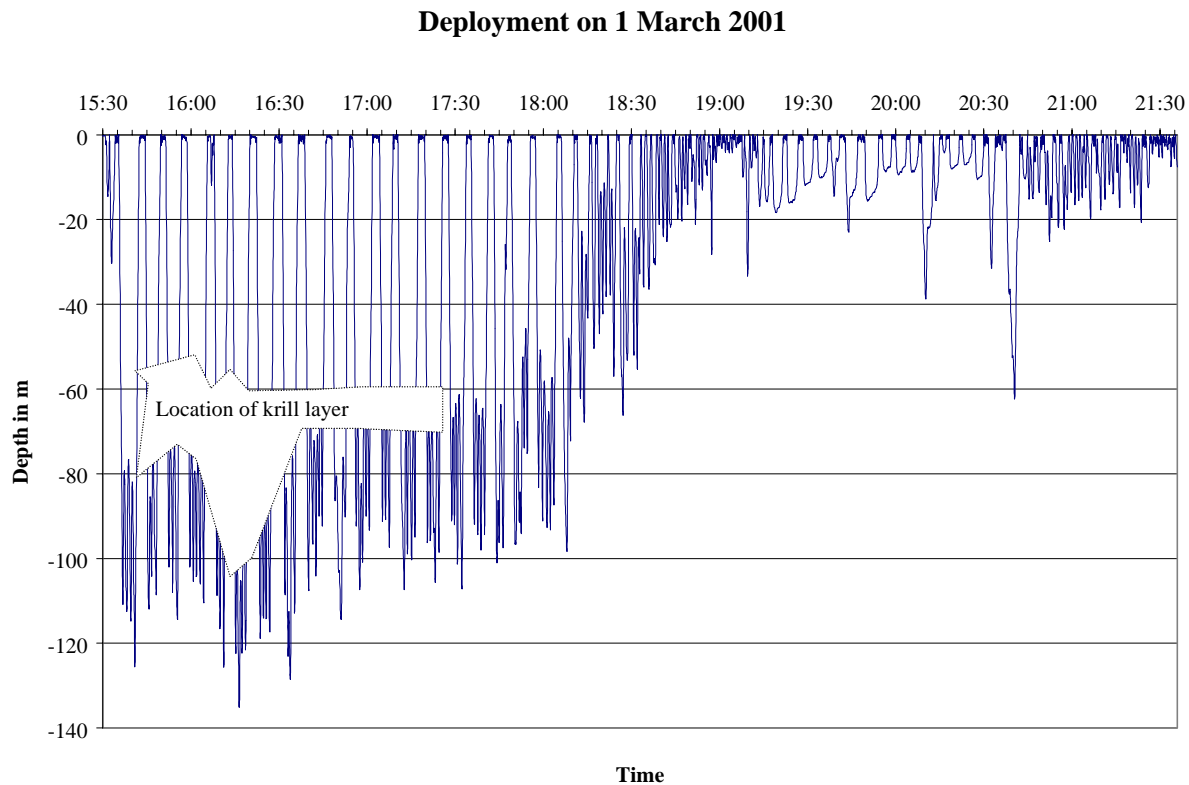
**Monterey Bay:** Crittercam deployments and recoveries in 2000 were made in Monterey Bay from 12 to 19 September 2000. Six approaches were made to blue whales to attach Crittercams; in three of these approaches we made physical contact with the whale and achieved one successful deployment. Through this effort we improved our strategy for approaching whales. The successful deployment was made on the lead whale of a pair of whales on 14 September at 0947 h at 36°48.02N and 121°57.40W (Figure 2). The crittercam stayed on the whale throughout that day's observations even though we expected the corroding magnesium to result in breaking the vacuum holding the suction cup on to occur in about three hours. We were able to stay with the two whales through 1949 h after which deteriorating weather and decreasing light resulted in our losing the whales. The whales did not appear to change their milling behavior immediately after tag attachment. We did lose track of the whales for over one hour in the morning. Recovering the Crittercam proved challenging but was eventually achieved 3 days later on 17 September. By this time the combination of movement on the whale and drift after release had taken the tag to 36°31.57N and 122°17.80W or 23.2 nmi (43 km) from the location of attachment. Some data were lost due to the long time between tagging and recovery (a small amount of moisture condensed in the Crittercam casing). Both the lead animal that was tagged and the trailing animal in the pair were previously identified whales for which we have long sighting histories. The animal on which the tag was deployed was ID# 111 and had been first identified in 1987 in the Gulf of the Farallones. It has been seen since then in 1990 in the Gulf of the Farallones and in 1992 off both Fort Bragg and Point Arena. The trailing animal in this pair was also a known older animal (ID# 283) first identified in 1988 in the Gulf of the Farallones and seen in 1989 in Mexico and in 1992 in both Santa Barbara Channel and the Gulf of the Farallones.



**Figure 2.** *Movements of blue whale after attachment of Crittercam on 14 September 2000 in Monterey Bay.*

**Sea of Cortez:** Field effort was conducted in the Sea of Cortez in collaboration with Diane Gendron of CICIMAR primarily from 26 February to 6 March 2001 with 16 deployments attempted between 28 February and 3 March. One extended deployment and recovery was achieved on a single feeding blue whales on 1 March (Figure 3). We achieved another extended deployment on 3 March but despite an extensive search extending after our field effort, it was never recovered. Data from the primary deployment covered more than 6 hours extending from daylight into night and showing the dramatic

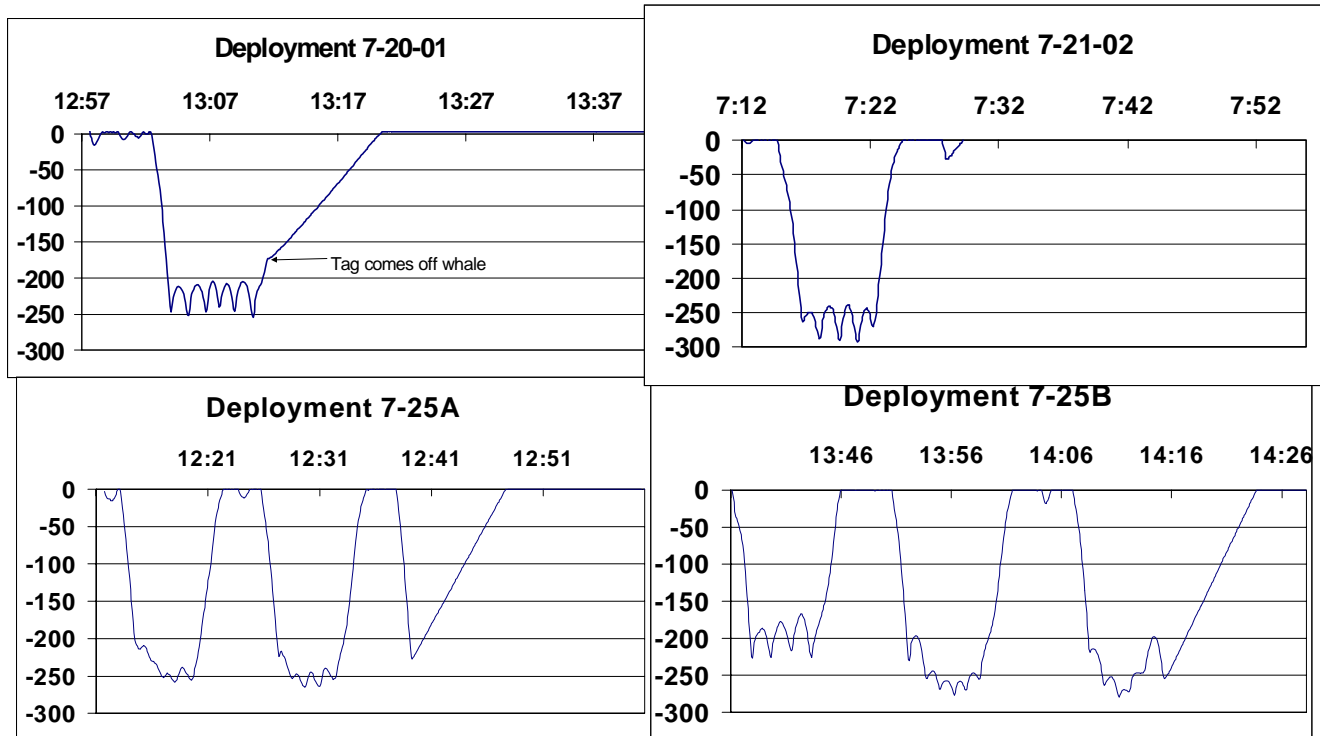
shift in depths of dives (Figure 3). Comparison of the dive profile of this animal with the presence of a krill layer detected from a boat following behind the whale showed it was diving to below the krill layer and then coming into the lower portion of the layer. That observation and the collection of feces confirmed they were feeding in this area. Depth of feeding dives became progressively shallower into the evening in response to the vertical migration of prey. After 1830 h dives became shorter (<5 min), with all but one dive was shallower than 40 m and the sawtooth feeding dives were no longer seen. After 2045, dive interval became even shorter (1-2 min) and the whales primarily stayed shallower than 20 m. Identification photographs were obtained of most of the animals in this area and skin samples collected from many of them.



*Figure 3. Dive record from Crittercam deployment on 1 March 2001 in the Sea of Cortez.*

**Southern California:** Our third deployment effort under this grant was conducted in the southern California Bight from 14 to 26 July 2001. We had planned to work with the concentration of blue whales that typically feeds in the Santa Barbara Channel during this period. Unfortunately, there were very few blue whales present this year. We were able to discover two other areas with large blue whale concentrations just north of San Nicholas Island and southwest of San Miguel Island. Although both these areas were close to 50 nmi away from the nearest harbor, we were still able to effectively work in these areas with our two RHIBs. The concentration of blue whales off San Miguel Island was one of the largest we have ever documented with over 200 animals in an area less than 10 by 2 nmi. We had excellent success deploying Crittercams achieving 12 deployments, 5 of these for periods of greater than 15 minutes where the camera was recovered. We lost one camera, we suspect due to failure of the VHF transmitter, although this tag may still be recovered if it washes up on shore.

Deployments during this period revealed whales were diving down to depths of 250 to 300 m and generally for durations of 8-11 min. This is both longer and deeper than has generally been found for blue whales. The Crittercam tapes revealed an extremely dense layer of krill was present in this area and extended from just below the surface down to the maximum depths of close to 300 m. Despite the wide layer of krill, the blue whales were feeding close to the bottom and at the lower depths of this krill layer. One deployment with the tag more on the side of the whale clearly showed the throat pleats distending as it conducts a lunge providing confirmation that these underwater saw-tooth dives are underwater feeding lunges into layers of krill.



*Figure 4. Dive behavior of blue whales tagged off San Nicolas Island on 20 and 21 July 2001 and off San Miguel Island on 25 July 2001, showing long deep dives. Straight line assents at the end of each tag series is drift as camera floats to surface after detachment.*

## CONCLUSIONS

A number of valuable things were learned from these deployments, including:

1. Developing more effective approach methods for blue whales to deploy instruments; our success rate in attachment has gone from <10% of approaches where we contact the whale to 46%.
2. Improving of the performance of the Crittercams themselves including improvements in sound quality and more effective and redundant release mechanisms.
3. Obtaining images of underwater behavior in conjunction with acoustical recordings and dive records of multiple animals in different regions and seasons. Underwater video has revealed diving behavior (Williams et al 2000) as well as feeding strategies.

These have provided a number of insights into the underwater behavior of blue whales including:

1. Confirmation through visual and sound that whales are generally feeding by conducting multiple upward lunges into prey.
2. In cases where the depth of the krill layer was determined, the whales were coming into the krill layer from below and they were inverting as they made their lunge up into the krill layer.
3. We were able to confirm that the lunges brought the whales to near stand-still within dense layers of krill.
4. Blue whales were diving deeper than had previously been reported during our deployments in the Southern California Bight (off San Nicolas and San Miguel Islands) feeding on krill layers near the bottom at water depths down to 300 m.
5. Examination of audio tracks indicates most animals are not vocalizing during feeding.
6. There was not evidence of close spacing or coordination between pairs of whales suggesting that pairing was for a different purpose than cooperative feeding.

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