

## **Behavioral and Physiological Response of Baleen Whales to Ships and Ship Noise**

John Calambokidis  
Cascadia Research Collective  
218 ½ W, 4<sup>th</sup> Ave.  
Olympia, WA 98501  
phone: (360) 943-7325 fax: (360) 943-7026 email: [calambokidis@cascadiaresearch.org](mailto:calambokidis@cascadiaresearch.org)

Collaborators: SW Fisheries Science Center (Kellar), Moss Landing Marine Labs (Harvey and Szesciorka), SEA (Southall), Stanford Univ. (Goldbogen), Oregon State Univ. (Friedlaender)

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### **LONG-TERM GOALS**

This study began in late 2013 with the primary goal of examining the behavioral and physiological response of baleen whales to ships and ship noise off California using a combination of opportunistic and controlled research. Ship noise has been identified as the major source of anthropogenic noise in the oceans especially in areas of high vessel traffic. Ship strikes are also a growing concern especially for several species including blue and right whales that appear to be particularly susceptible. Initial research demonstrated the feasibility of documenting whale response to opportunistic close approaches of ships in areas of high levels of ship traffic particularly near known high concentrations of whales off California. This juxtaposition has resulted in high levels of ship strikes (Berman-Kowalewski et al. 2010) as well as potential impacts of ship noise on blue whales (Melcon et al. 2012) and other species. In this study we continue research on behavioral response of baleen whales to ship close approaches and specifically examine how this varies with ship speed; one strategy proposed to mitigate ship strikes. We will also test the response of blue whales to controlled playback of ship noise to determine the cues blue whales respond to and also to allow comparison between the response to ship noise and other anthropogenic sounds like mid-frequency sonar. To gain insight into whether ship noise and frequent passages of ships might be causing a stress response, the study includes collaboration with SWFSC to compare stress hormone levels in blue whales feeding for extended periods in areas of high ship traffic with those feeding away from shipping lanes.

### **OBJECTIVES**

Our objectives include:

1. Determine behavioral response (avoidance and changes in dive behavior) of blue whales and other large mystecetes to exposure to close approaches by ships.
2. Examine the stimulus that appears to trigger the response to ships and whether this is a response to ship noise or the presence of the ship.

3. Examine how reaction varies with differences in ship speed and approach.
4. Determine sound exposure of a whale directly in the path of a ship.
5. Examine whether chronic exposure to ship noise causes a noticeable change in stress hormones (Kellar et al. 2006, 2009).

## **APPROACH**

Our overall approach to achieve our objectives involves:

- Continuation of the work on reaction of whales to ships focused on increasing sample size of ships moving at different speeds and additional species of whales. Focus would include work with full speed ships in the Santa Barbara Channel (now that 1 December 2011 changes in the CARB regulations on clean burning fuel are resulting in ships returning to the shipping lanes through the Channel) and slower ships near the entrances to Los Angeles/Long Beach Harbors.
- Conduct controlled exposure experiments (CEE) using ship noise to blue whales using identical methodologies to the SOCAL BRS (Southall et al. 2012, 2013) to allow direct comparison of blue whale response to ship noise to that from other anthropogenic sources like mid-frequency sonar (MFA). Response to playback may or may not be similar to the response to close approaches of real ships being conducted opportunistically. This will also allow comparison to the response of right whales to ship noise from distant ships and playback (Nowacek et al. 2004) using somewhat similar methodologies.
- Obtain measurements of ship noise in the path of ships representing what whales at risk of a ship strike would experience using autonomous drifting recording hydrophones in the path of ships.
- Collect and examine stress hormone levels in biopsy samples from blue whales feeding in areas of high ship traffic such as off LA/Long Beach Harbor, especially over multiple days, compared to those from blue whales feeding farther from shipping lanes.

## **WORK COMPLETED**

Work began on the study in mid to late 2013 so only initial project activities occurred in FY2014.

Work completed to date includes:

1. Continued collaboration with Moss Landing Marine Laboratories (Dr. Jim Harvey and graduate student Angela Szesciorka) on tag designs to provide longer term deployments of archival tags especially for work with humpback whales off northern California.
2. Conduct test deployments of dart-attached archival tags in 2014 on humpback whales in Monterey Bay and the Gulf of the Farallones on humpback whales to tests different dart attachment configurations and develop a new longer term dart-attached archival tag system.
3. Successfully conducted 37 deployment of tags on blue and humpback whales in 2014 S California, Gulf of the Farallones, and Monterey Bay especially in and around shipping lanes collecting 1,169 hours of data (Table 1). The record hours of data was primarily the result of the 10 dart-attached tags which accounted for 1,004 hours.

4. Conducted a successful cruise with Channel Islands National Marine Sanctuary utilizing their vessel *Shearwater* in 2014 off southern California which included surveys of S California shipping lanes, successful deployment of 3 types of archival tags, and acoustic monitoring of ships in the shipping lanes. Timing of cruise coincided with CINMS incentive program to slow ship speeds and successful monitoring associated with these transits.
5. Collected initial samples for stress hormone evaluation being conducted in coordination with collaborators at SWFSC for testing of stress hormones in later stages of this project.
6. Submitted and received positive reviews on manuscript submitted to Endangered Species Research titled "Simultaneous tracking of blue whales and large ships demonstrate only limited behavioral responses for avoiding collision" which summarizes research to date and follows up previous work (McKenna et al. 2011, Calambokidis et al. 2011, 2013).
7. Work has continued on the SOCAL Behavioral Response Study (under separate funding) which provided some important information on blue whale behavior and response to ships off the LA/Long Beach area incidental to sonar testing and will also provide data on response of blue whales to Navy sonar that will serve as an important basis of comparison to controlled ship noise exposure results from this study.
8. Deployed 12 acoustic recording buoys in and near shipping routes to obtain measurements of ship noise in the path of ships.
9. Preliminary work with Customized Animal Tracking Solutions to add additional high sample rate accelerometer and other ancillary data to the GPS tags to better monitor calling behavior and kinematics.

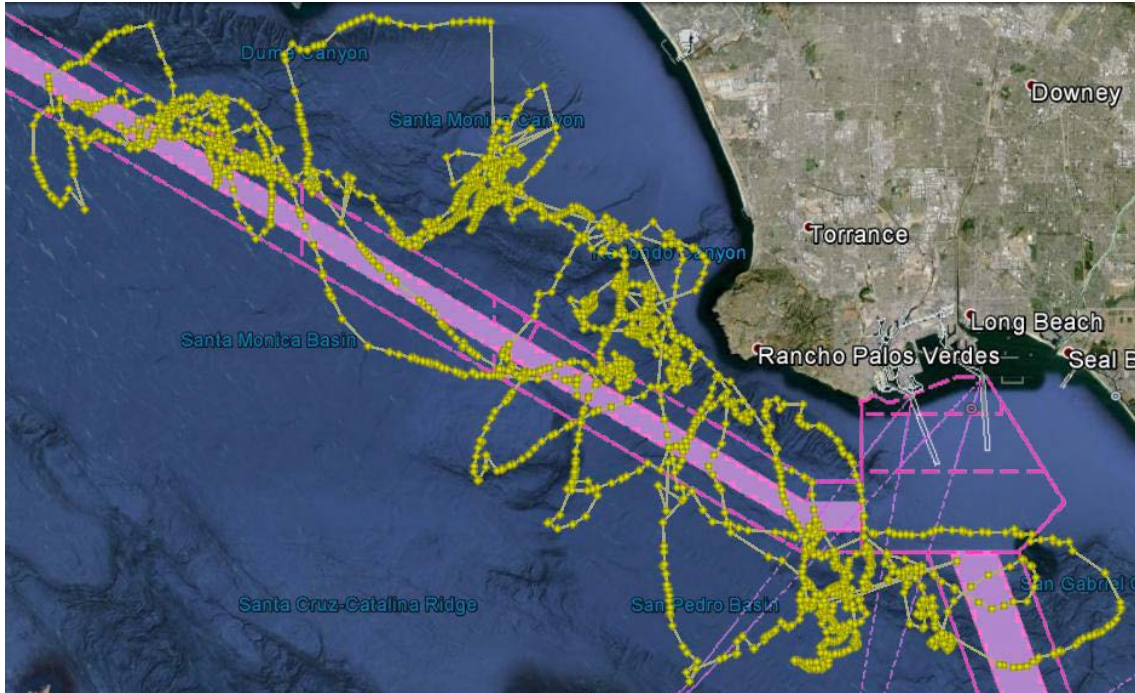
## RESULTS

Effort in 2014 represented the first full year of this project (Awarded in Sept 2013 with a start date of 15 August 2013). The successful development and testing of a dart attachment system for archival tags was put into use and dramatically increased our ability to gather longer term data on whale movements and behavior in and around ships. Dart attachments provided detailed diving and GPS data for up to 3 weeks.

***Table 1. Summary of hours of tag data obtained from 37 tag deployments on blue and humpback whales in 2014 as a part of this project. The Dtag3 deployment conducted concurrent with the SOCAL-Behavioral Response Study.***

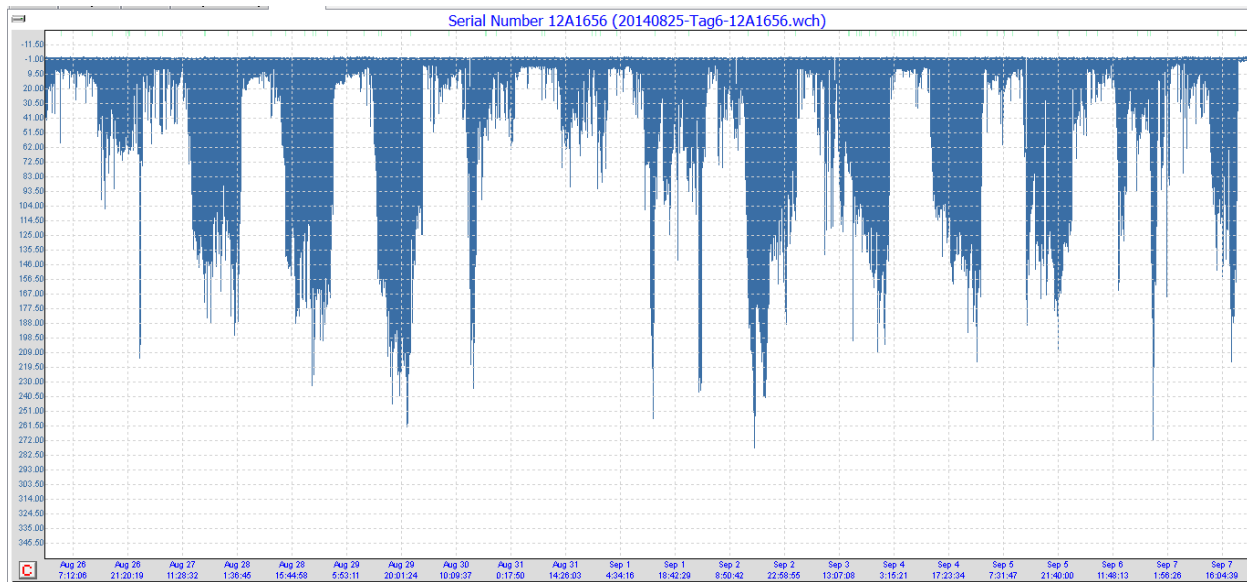
Tag Type	No. Deplmts	Hours of data		
		Blue	Humpback	Total
Acousonde	1	5		5
Dtag3	1	6		6
Mk10F-GPS Suction Cup	15	85	67	152
Mk10F-GPS-Dart attached	10	893	111	1004
Video tag	10	3		3
Total	37	991	178	1169

Once the final design of the dart attachment was implemented the four deployments on blue whales averaged 223 hours each. These yielded far more detailed insights into the movements and diving of these whales. The two longest deployments were on an individual that spent the entire tag period of just over 308 hours feeding in and around the shipping lanes off LA/Long Beach (Figure 1). Dive records on this individual provided excellent documentation of the diurnal variation in feeding and depth as well as the shifting from shallow to deep feeding (Figure 2). Overlap with shipping lanes occurred in a number of locations and analysis of proximity and close approaches of ship is underway.



***Figure 1. Fastlock GPS positions of a blue whale tagged with a dart attached archival TDR-10F tag from 25 August to 7 September 2014 and stayed in the LA/Long Beach area.***

Our longest deployment was on a blue whale near the LA/Long Beach shipping lanes but then traveled south, intermittently feeding (Figure 3). This animal continued south before the tag came off approximately 100 mile SE of Magdalena Bay. The satellite transmitter provided approximate positions of the whales movement and the timing and location of the tag coming off so we could conduct a recovery of the tag (made more complicated by the location and the passage of a hurricane hitting Baja when it was released. The tag battery was exhausted but had sampled up to within a day of when it came off the whale.

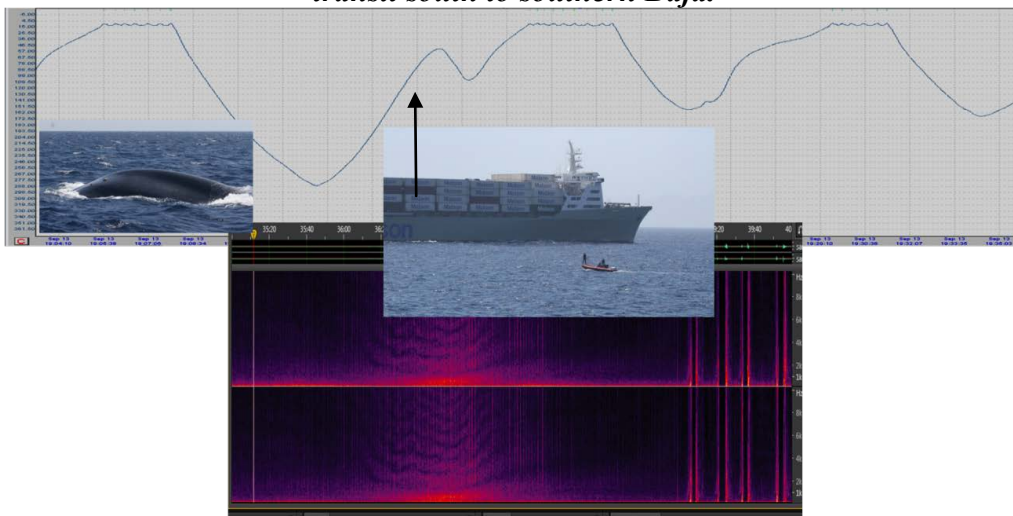


**Figure 2. Dive record of a blue whale tagged with a dart attached archival TDR-10F tag from 25 August to 7 September 2014 and stayed in the LA/Long Beach area.**

Another key result in 2014 has been the most detailed documentation of the response and acoustic exposure of a blue whale that was nearly hit by a ship off LA/Long Beach (Figure 4). This particular deployment occurred in September 2014 when research was being conducted near LA/Long Beach in conjunction with the SOCAL Behavioral Response Study. The blue whale had been tagged with both a suction cup GPS tag as a part of this study and a Dtag3 acoustic tag for the SOCAL-BRS. A controlled exposure experiment with playback of mid-frequency sonar sounds was conducted with a scaled sound source as a part of the SOCAL BRS procedure (Southall et al 2013). After the end of the CEE monitoring continued of the whale and both tags stayed on (the Dtag3 past the programmed release time). The whale encountered an outgoing cargo ship that passed directly over the whale's track while the whale was underwater (the whale surfaced on the other side of the ships wake immediately after passage). The dive record shows a clear alteration in diving behavior at the estimated closest approach with the whale terminating its ascent and descending until after the ship passage (Figure 4). The sound record shows loud ship noise and will provide a clear measure of the sound level at the time of behavior change. One goal of this study was to contrast behavioral response of whales to sonar and ship noise but it was unanticipated this occur in such dramatic fashion on the same deployment. Some of this data was in jeopardy when the Dtag3 not only failed to release due to water intrusion but also possibly failed to transmit since it could not be located by VHF and was feared lost until a kayaker spotted it floating off La Jolla and recovered it. while the Dtag failed while on the whale it had recorded and the data was recovered for the period through both the CEE and the ship close approach.



**Figure 3. Fastlock GPS track of blue whale tagged with dart-attached archival TDR-10F from 25 August to 12 September 2014 that spent time in shipping lanes off LA-Long Beach before making transit south to southern Baja.**



**Figure 4. Close encounter with a ship documented with both Dtag and TDR-10F tags off LA/Long Beach on 13 September 2014. This deployment was also part of the SOCAL-BRS and a controlled exposure conducted an hour and a half earlier. Photo at top left shows tagged whale, middle photo ship passing focal follow/tagging vessel that had to break off to avoid ship, top figure shows dive record for whale around the time of ship closest approach (marked with arrow) estimated by tracking vessel, bottom panel shows sound spectrum showing ship noise from DTAG.**

## RELATED PROJECTS

This project is being conducted in collaboration with several other related efforts:

1. Collaboration with Moss Landing Marine Laboratories (Dr. Jim Harvey and graduate student Angela Szesciorka) on tag designs to provide longer term deployments of archival tags especially for work with humpback whales off northern California.
2. Collaborators with Dr. Nick Kellar at SWFSC who will be receiving funding from ONR for the testing of stress hormones in later stages of this project. This component while an integral part of this study is being funded separately from our award because it is going to another federal agency.
3. Field effort in 2013 was conducted in coordination and with support of NOAA including the Channel Islands National Marine Sanctuary as a part of an ongoing project examining ship strike risk to whales off California.
4. The SOCAL Behavioral Response Study to Navy sonar (funded by the Navy's Living Marine Resources program) will serve as an important basis of comparison for results from this study and there was some cross over in data obtained (see above).

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