# Acoustic Behavior, Baseline Ecology and Habitat Use of Pelagic Odontocete Species of Concern

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## LONG-TERM GOALS

Obtain critical sound use, behavioral ecology, and fine-scale habitat use information of two pelagic species of odontocete cetaceans which inhabit regions of significant U.S. Naval operations and may be impacted by coincident Naval training activities. The goal is to establish baseline acoustics, behavior and ecology of these species to predict and mitigate potential human impacts. Information gained will provide a context for evaluating natural behavioral ecology and potential responses to anthropogenic sounds.

## OBJECTIVES

Through detailed, non-invasive, bioacoustic behavior measurements:

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1) Quantitatively assess the acoustic signals of Hawaiian insular false killer whales (FKWs) and melon-headed whales (MHWs).

2) Determine baseline acoustic behavior, basic activities, detailed dive patterns and fine-scale habitat use for both species.

3) Pair data on the acoustic characteristics of calls with behavioral ecology information to evaluate the potential for species classification, passive acoustic detection, and density estimates.

## APPROACH

Data are being collected with non-invasive, suction cup tags (DTAG3) (Johnson and Tyack 2003) attached to individual Hawaiian insular false killer and melon-headed whales. This project is being conducted over four, 10 day to 3-week tagging periods spread between three years. Tagging operations are conducted in the main Hawaiian Islands. For some of the field operations two vessels are used searching in different areas to maximize the likelihood of encountering target species. Once a group is sighted, the boat gradually approaches whales for tagging using a carbon fiber pole with tag attached. Both FKWs and MHWs are easily approachable, typically showing no avoidance behavior and often regularly approach small vessels to bowride. Individuals are photo-identified to determine patterns of individual, group, and population affiliation (Baird et al. 2008) and for later comparison to ensure no lasting effects of the suction-cup tags. Ancillary data including group size, location and accompanying species of birds, fish and marine mammals are also recorded. Groups are then approached to a shorter range (3-5 m) for tagging. Tag attachments are digitally recorded by video and still camera to document any behavioral reactions. The vessel paths and tag deployment positions are noted via GPS coordinates. Goal tag durations are 2-8 hrs depending on the time of day and location the group is encountered. Tagging is being conducted and leveraged with ongoing satellite tagging operations of false killer whales and other species being funded to Cascadia Research Collective. This has the advantage of dissipating tagging operations costs and increasing available field time.

**Analysis:** The analyses are currently being identified as (i) acoustic classifications (e.g. peak frequency, bandwidths, centroid frequency) (ii) acoustic behaviors (dive and movement analyses associated with the sounds produced). Current analyses underway are described in the Results section.

Data are reviewed in the field to insure accurate recordings but primary analysis occurs in concert at the Marine Mammal Behavior (Tyack) and Sensory Ecology (Mooney) Labs at WHOI. We will coordinate the acoustic analyses with the Marine Mammal Research Program (Nachtigall-U. Hawaii) and graduate student Aliza Milette. An additional portion of the analyses will be addressed by WHOI Joint Program graduate student Max Kaplan. In addition to assisting in the field work, Ms. Milette, and Co-PI Nachtigall, are conducting a laboratory study with a trained false at the University of Hawaii's Marine Mammal Research Program. They are: (1) examining a FKWs' acoustic output and how signals are translated on the D-tag recordings from both the tagged animal and from other sources and (2) identifying how components of complex social signals are received by the animal when they are produced from different locations. These analyses will contribute to the graduate education of Ms. Millete and Mr. Kaplan.

## WORK COMPLETED

Three field efforts have been conducted. They include: (1) Oct 18-Nov 15, 2011 (2) May 5-May 25, and (3) Aug 7-Aug 27. These three efforts have been based from Kona Hawaii and have logged 64 days at sea, with two vessels operating for 22 of those days. One additional cruise is planned for 2013. Field efforts were coordinated with a NOPP/ONR funded project to Alaska SeaLife Center (R. Andrews) and Cascadia Research, as well as a PIFSC funded project to Cascadia Research, to increase the field time available for working with target species and potential tagging.

During cruise 1 and 2, the DTAGv3 were deployed. Based on the tag results from these trials, as well as other projects, this version of the DTAG was revised. We were the first to deploy this new version of the tag (DTAG v3.2) during our third research cruise in Aug 2012. In total, we have spent 64 days at sea, with 84 boat days (due to leveraging sea time with concurrent projects, we were sometimes operating two boats). This covered approximately 10,393 km. We have had 286 cetacean sightings (mean = 95.3 / trip). Of these, 7 included our target species (6 sightings of MHWs, 1 of FKWs) (Figure 1). We deployed 15 DTAGs in all, 9 on MHW, and 1 on a FKW (5 tag deployments were on short-finned pilot whales, in collaboration with other projects). One of the MHW tags was deoployed on an individual from the main Hawaiian Island population. The rest were deployed on Hawaii Island resident population individuals. Data from these two groups will facilitate potential population comparisions. The DTAGs have been deployed on target species for at total of 8:27:54 (hr:min:sec), including 3:12:19 for the FKW and 5:15:35 on MHWs. In addition, we have 320 min of far-field recordings with MHWs using two different DMON approaches. Thus, in total this is over 13 hrs and 24 min of baseline acoustic and behavioral recordings for our goal species, FKWs and MHWs.

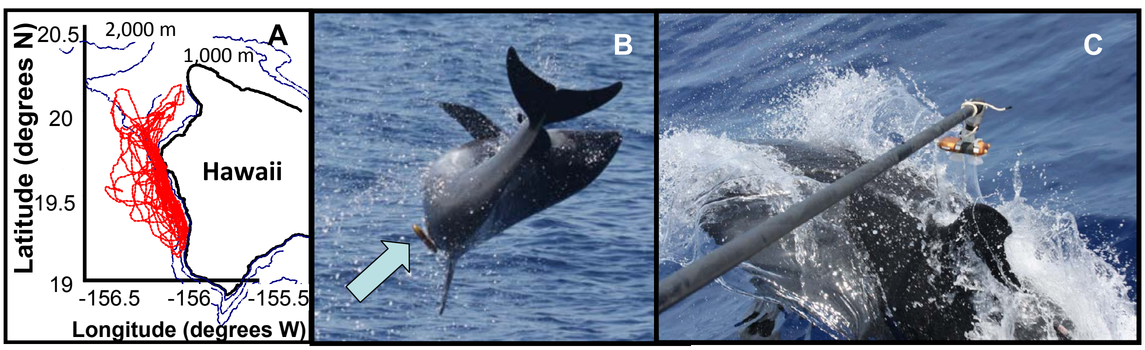


***Figure 1. (A) Tracklines (red ) from first field effort in which we covered 3,993 km in 27 days on the water (with two boats operating on six of the days), and had 101 sightings of 13 species of odontocetes. (B) DTAG3 on a melon-headed whale (arrow). (C) Deployment of a DTAG3 on a false killer whale (photos taken under NMFS permit # 15530 to CRC).***

## RESULTS

All three field seasons to date have resulted in multiple successful tag deployments. DTAG acoustic recordings have been acquired for both species.

Data from the tagged false killer whale shows that both acoustic and dive behavior were significantly different during apparent forging events and the travel period (Figure 2A). Foraging events were noted by the chasing and capture of mahi mahi, and the travel was documented as a directional movement of the animals at a relatively rapid speed with no signs of foraging. The tagged record can be divided between the first (foraging) and last 100 min (travel). Dives were deeper (17.8 m vs. 12.6 m) and 3 times more frequent during the foraging event. The vocalization (clicks and whistles) rate of the tagged animal was substantially higher during the apparent foraging event. Sounds were noted from the tagged animal and nearby conspecifics. During the apparent travel period only one event of 12:31 (min:s) duration was noted to have occasional clicks and whistles by the tagged animal and nearby conspecifics. In comparison, both clicks and whistles of the tagged animal, and conspecifics, were repeatedly observed in the entire first 100 min of the record.

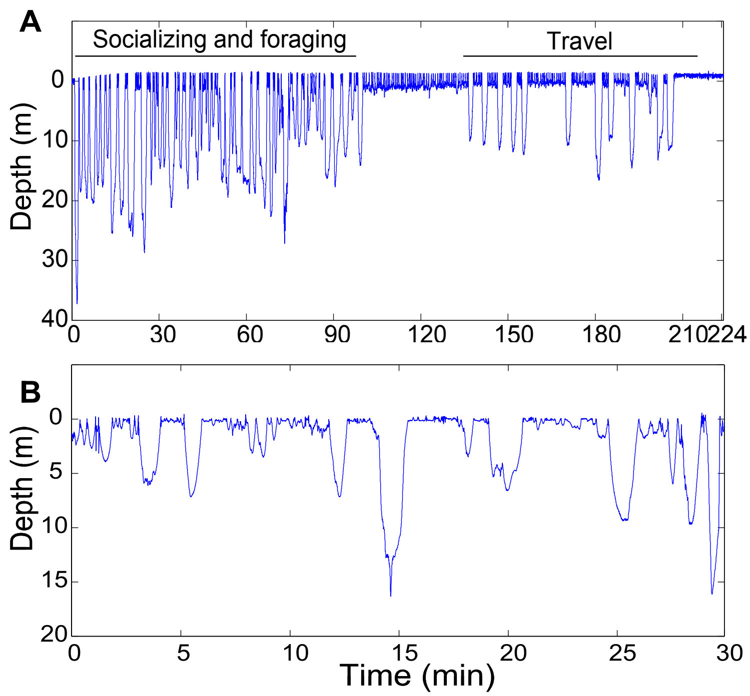


***Figure 2. Dive profiles of a false killer whale (A) and melon-headed whale (B). False killer whales were slightly deeper in dive depth. Sound production was almost exclusively during the foraging period (first 100 min), with few sounds (primarily clicks) during travel. During melon-headed whale tagging, sounds (primarily frequency modulated whistles) of the tagged animal and conspecifics were recorded near continuously, including during all dives and directional movements.***

During the observed foraging period both whistles and clicks were repeatedly noted from both the tagged animal and the nearby conspecifics. Clicks and whistles from the apparent tagged whale were frequently overlapping, with 71% whistles observed to be coincident with clicks. Whistles were relatively constant frequency with few inflection points (Figure 3A). Overall, there were few overlapping signals between apparent sounds from the tagged animal and sounds from conspecifics.

Melon-headed whale tag data reflected relatively shallow dive behavior during the daytime tag period. All dives were less than 20 m (Figure 2B). The group tagged was highly vocal with sounds recorded almost continuously by the tag. While some signals were apparently from the tagged animal, the majority of signals were of lower received amplitude and from nearby conspecifics. Whistle contours varied considerably. Fundamental energy was largely below 14 kHz.

One particular challenge with melon-headed whales is that they often shed the tag before the designated tag-detachment period. The advantage of this is that we repeatedly noted (five of ten animals) that when the tagged animal sheds the tag, it turns to echolocate at the tag (Figure 3B). This provides on-axis clicks that are often difficult to acquire via DTAG data due to the placement of the tag on the tagged animal's back. These on-axis signals will facilitate quantification of the acoustic signals.

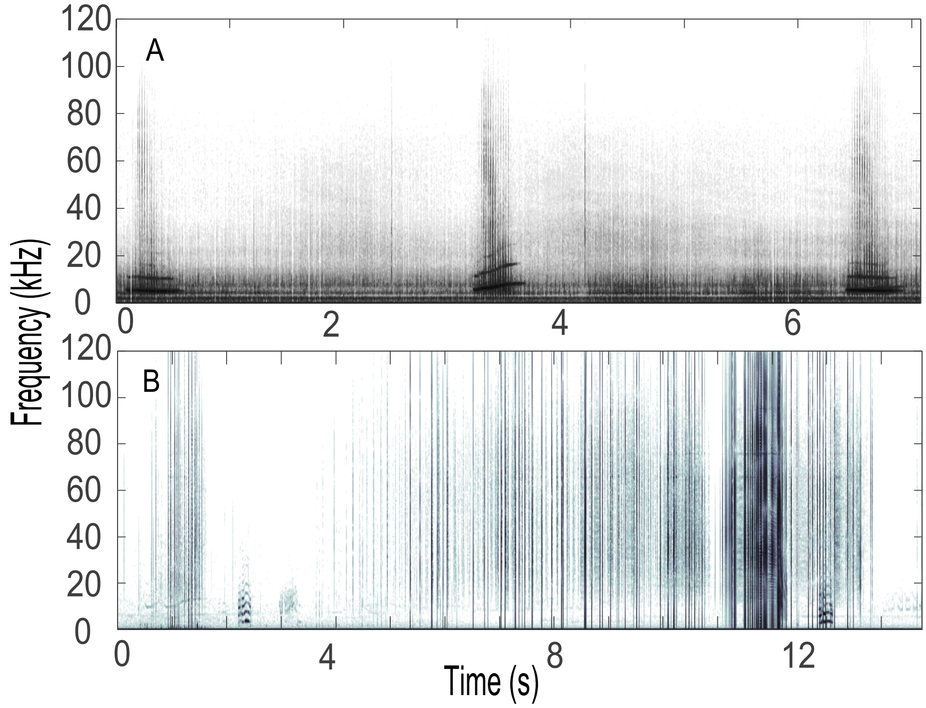


***Figure 3. (A) Combined whistle-click signals produced by the tagged false killer whale during the foraging period. The "typical" whistle contours shown are nearly linear, with few modulations often seen in dolphin clicks. (B) A series of melon-headed whale clicks directed at the tag immediately after the animal shed the DTAG.***

The specific analyses are ongoing and are incorporating data from the tagged animal, or if possible, from its conspecifics. From the tagged animal we are addressing: vocalization rates, inter-click-intervals, dive rates, dive angles, accelerations, and swimming speeds during surface-observed activities. From conspecifics echolocating toward the tagged animal (or from the tagged animal echolocating on the released tag) we are gaining: click duration, peak frequency, bandwidths, centroid frequency, and will incorporate descriptions of max, min, mean, median, and range of frequencies. Assessment of on and off-axis clicks include: click rates and click types. Classifying these clicks may be dependent upon click types, such as buzzes vs. standard clicks.

Addition to analyses of these Hawaii data, we are, currently comparing signal structure and acoustic behavior indentified here to those collected for the same species in the Atlantic (Bahamas). This will facilitate comparisons to identify potential acoustic differences between populations. Because we have significant far-field acoustic data from MHWs and a non-target species, (*Steno brenadensis*), we are evaluating a comparison between these two species. Initial whistle data reveals both species reflect signals with multiple inversions (i.e., modulated up, down, up), as opposed to more constant frequency signals of FKW.

With these characterizations we are planning on collaborations to enhance acoustic classifiers of FKWs and MHWs (e.g., Oswald et al. 2003; Oswald et al. 2004). Sound types will be compared to dive movement and behavior, examining prevalence of sounds in various parts of the dive as well as vocalization rates.  This information, along with the acoustic definitions, is expected to provide early indications of how acoustic classification and detection methods will proceed for these species. All data will finally be compared with non-tag data of habitat (depth, bottom contours, surface seawater temperature, bird presence), group composition, and behavioral state.

During these field projects 24 LIMPET satellite tags were deployed on 7 species, including location-dive tags (Mk10A) on four species (including two on melon-headed whales, providing the long-term dive behavior information for this species). Information from the LIMPET tag deployments (Figure 4) will also serve to help in the interpretation of the DTAG data.

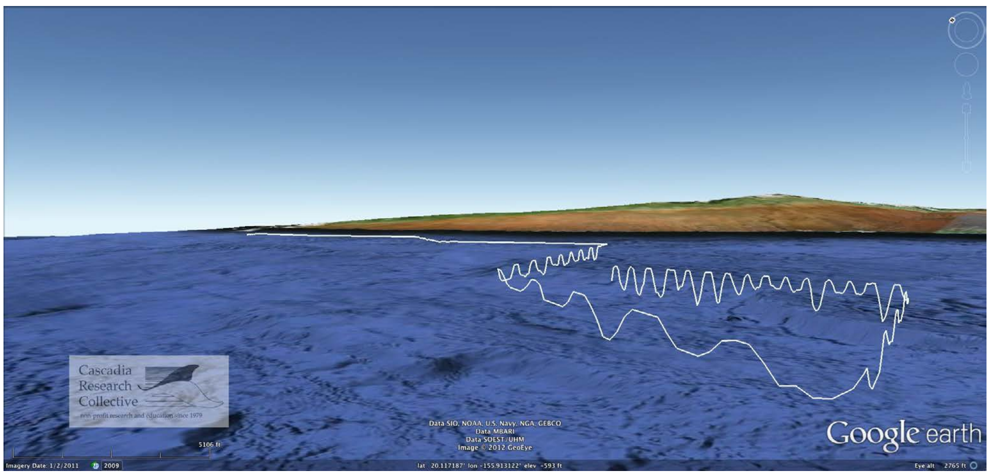


***Figure 4. Combination of location and dive data obtained from a location/dive LIMPET satellite tag attached to a melon-headed whale in August 2012. This figure shows an 11-hour period in September 2012, with deep dives (>300 m) to or close to the sea floor at night, and a period where the individual remained close to the surface during the late night/early morning (to the left side of the image).***

*DMON Applications*

In addition to the tagging work we adapted a complimentary project funded by the WHOI-Marine Mammal Center to develop and deploy both a DMON towfish and a DMON focal drifter. This work was very successful in the recordings made and the data collected. In the case of the melon-headed whale tagging in August 2012, we were able to deploy a DTAG, the towfish and the drifter simultaneously. This resulted in an immense amount of bioacoustic data, of which analyses are now underway. This includes individual call rates of whistles and clicks by the tagged animal, far field acoustic recordings (available for detailed acoustic characterizations) from the tag (of conspecifics) and DMONs, linking in time (for potential localization of the tagged animal) of the three concurrently deployed devices,  These far-field acoustic records are complimenting the often near-field acoustic records of the DTAG recordings.

Data analyses and scientific research papers underway include:

(a) Broadband acoustic characterization of the whistles and clicks of Hawaiian false killer whales. The results will be compared to DTAG data from the same species in the Bahamas (an Atlantic population).

(b) Broadband acoustic characterization of melon-headed whales and rough toothed dolphin (*Steno brenadensis*) whistles and clicks. These data are recorded from the DTAG, DMON towfish and DMON drifter.

(c) Comparison of the dive and acoustic behavior (movement/dive data associated with acoustic recordings) of Hawaiian and Bahamas false killer whales and melon-headed whales.

## IMPACT/APPLICATIONS

This research will provide necessary baseline sound-use and dive behavior data on two cetacean species of concern which occupy waters frequently used in U.S. Naval training operations. This work will improve our understanding of the acoustics, dive behavior and habitat use of two odontocetes species with significant anthropogenic interactions: the insular Hawaiian false killer whale, a species-of-concern, petitioned to be listed as an endangered species, and the melon-headed whale, a species recently involved in a near mass-stranding event following naval activities. Few acoustic or behavioral data exist for either species in the wild. These results will provide vital baseline information on the vocalization characteristics and use of sound by both species. These data as well as dive related acoustic behavior and habitat use will provide novel biological information for pelagic odontocetes with implications for monitoring and acoustic detection. Data collected will provide a context for studying behavioral responses to anthropogenic influences such as sonar sounds. Information can be applied to future acoustic detection models, predicting areas of cetacean occurrence, means of mitigating potential sonar-induced impacts, supporting encounter avoidance and assessing future effects.

## RELATED PROJECTS

ONR: Tagging and Playback Studies to Toothed Whales; Award Number: N00014-09-1-0528

ONR: Improving attachments of remotely-deployed dorsal fin-mounted tags: tissue structure, hydrodynamics, in situ performance, and tagged animal follow up; Award Number: N00014-10-1-00686 (sub-award to Cascadia Research Collective). Our field efforts have been combined with those of this project to leverage available time for tagging.

WHOI-Marine Mammal Center: Look Who’s Talking: Identifying the bioacoustic signals of sound-sensitive cetaceans and new applications for the DMON.

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