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 for two pelagic species of odontocete cetaceans that 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:

1) Quantitatively examine 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 were collected with non-invasive, suction cup tags (DTAG3) (Johnson and Tyack 2003) attached to individual Hawaiian insular false killer *(Pseudorca crassidens*), melon-headed whales (*Peponocephala electra*), and other species as opportunities allow. This project was conducted over four, 10-day to 3-week tagging periods across three years. Tagging operations took place off the leeward (west) side of Hawaii Island, Hawaii. Using one or two small boats (<27') we traversed areas of likely occurrence [based on sighting and satellite tag data (Aschettino et al. 2009; Baird et al. 2010)] for the two target species. Once a group was sighted, the tagging boat gradually approached them for tagging. Both FKWs and MHWs are relatively approachable, typically showing little avoidance behavior and often regularly approach small vessels to bowride. Individuals were 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 were also recorded. Groups were then approached to a shorter range (3-5 m) for tagging using a carbon fiber pole. Tag attachments were digitally recorded by video and still camera to document any behavioral reactions. The vessel paths and tag deployment positions were noted via GPS coordinates. Goal tag durations were 2-8 hrs depending on the time of day and location the group was encountered. Tagging operations were conducted and leveraged with ongoing satellite tagging studies of false killer whales and other species (funded to Cascadia Research Collective). This had the advantage of distributing tagging operational costs and increasing available field time.

Analysis: The analyses are identified as (i) acoustic parameters of MHW signals (e.g., rate of tonal vs. pulsed production, and respective peak frequency, bandwidths, centroid frequency) (ii) fine-scale behaviors (dive and movement analyses) associated with the sounds produced, and (iii) transmission and shading of FKW signals. The analyses are underway and are described in the Results section.

Data were initially reviewed in the field to ensure accurate recordings but primary analyses occur in concert at the Marine Mammal Behavior (Tyack) and Sensory Ecology (Mooney) Labs at WHOI. We 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 DTAG 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

This year, the fourth field season was completed off the west side of Hawaii Island, from May 10-28th, 2013. We logged 2,644 km, had 57 sightings of nine species of cetaceans, and averaged three sightings per day. We made it into as the range of the Kohala resident MHWs multiple times and had two sightings (May 13 and 14). Groups were relatively small, approximately 18 and 55 individuals (resident population estimate is 447 animals and median group size is 275 individuals; Aschettino et al. 2011). These small groups did not allow close approaches for tagging, thus limited the tag success of target species for this trip. Thus, the last two field days, we tried an alternative strategy of leveraging the relatively new DTAG3s and collecting acoustic behavior data on additional species. Nine tags were deployed [six on pan-tropical spotted dolphins (*Stenella attenuata*) and three on short-finned pilot whales (*Globicephala macrorhynchus*); Table 1]. Five of the spotted dolphin tags were on their respective focal animal for significant amounts of time. These results reflected our abilities to deploy and collect data when opportunties were available. The pilot whale data will likely novel yield comparisons to CRC's long-term pilot whale population studies off the Kona Coast. The five tags deployed on the on pan-tropical spotted dolphins was a substantial advancement in biologging tag applications. Small pelagic delphinids have traditionally proved evasive for acoustic behavior tag deployments longer than several seconds. Small delphinids are the type of odontocete that DTAG3s were built to address; but there are few tests of the tags' efficacy. Our relatively large sample size, multiple tags deployed for the preset duration, two comparative groups, two separate days, animals potentially foraging, and groups with and without the pressence of fishing vessels opens the door for many new questions to be addressed here and in future studies.

Table 1. General DTAG deployment summary. Sa = Stenella attenuata; Gm = Globicephala macrorhynchus

Tag #	**Sa147a**	**Sa147b**	**Sa147c**	**Sa 147d**	**Sa146a**	**Sa146b**	**Gm145a**	**Gm145b**	**Gm145c**
Time of day deployed	10:05:11	10:10:20	10:19:18	11:19:36	9:45:40	10:03:53	12:57:51	1:21:01	2:58:30
Recording duration	0:00:29	0:41:55	4:28:42	8:39:24	2:12:20	1:44:41	0:59:39	2:28:59	2:07:30
Full deployment	No	No	Yes	Yes	Yes	No	No	Yes	Yes

In addition to the tag studies, we incorpated two additional recording devices into our protocol. We used a drifter buoy with a GPS link and broadband DMON recorder suspended at 15 m (Digital Acoustic Waterproof Gizmo – DAWG). The second was a towfish system incorporated with a broadband DMON (Figure 1B,C). This towfish was deployed during both MHW sightings. Together, these systems accounted for 19 additional acoustic recording deployments. After this field season, we have focused on data analyses, as noted above, to characterize the call parameters of MHWs (and several additional Hawaii odontocete species), as well as call and communication dirctionality of FKWs. During the field operations we were also able to opportunistically deploy satellite tags on two sperm whales (*Physeter macrocephalus*) and two short-finned pilot whales.

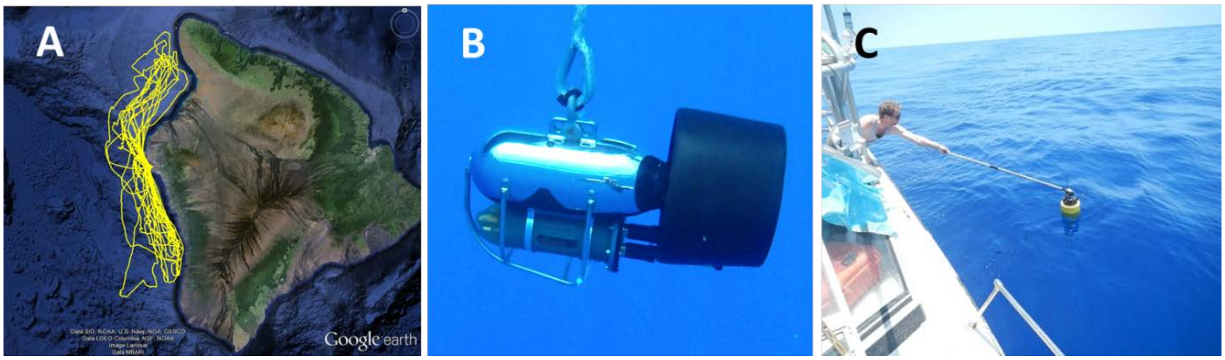

Figure 1. (A) Tracklines (yellow) from the field effort in which we covered 2,644 km in 19 days, and had 57 sightings of nine odontocetes species. (B) Towfish in the water with DMON (hydrophones forward). (C) Retrieval of the DAWG drifter buoy. The DAWG records broadband sound via a DMON suspended below. It also logs GPS location on board, and relays that location to a handheld receiving on the vessel.

In addition to the field work, we conducted a lab-based companion study using a trained FKW to examine (i) how outgoing signals (echolocation clicks and whistles) change dependent on a receiver's (the FKW) location and (2) how the receiver's head shapes that signal. A bottlenose dolphin (*Tursiops truncatus*), the signaler, and a false killer whale, the receiver, were both stationed underwater in separate hoops. In both paradigms the receiver was positioned at various angles from 0-180° from the signaler while wearing the DTAG. The DTAG was placed on mulitple locations on the body and lower jaw (addressing locations of ideal tag placement and those involved in sound reception). The characteristics of the signals recorded on the tag are referenced to concurrent calibrated-hydrophone recordings from in-front of the signaling animal. Signal parameters including sound pressure level, latency and frequency content are being compared to the various receiver and DTAG positions.

RESULTS

The DMON-based tools including the towfish and DAWG drifter significantly enhanced our ability to collect acoustic data. Winds were relatively light this past trip allowing many forrays into resident Hawaii Island MHW territory, but we sighted only two small groups on two days. This suggests that the majority of the population was elsewhere during the field season. Further, the small groups were difficult to approach closely for tagging (relative to larger groups). However, by deploying the towfish we were able to acquire 2:49:52 (hr:min:sec) of broadband acoustic data (from both groups). Acoustic signals were detected but at a substantially lower rate than with larger encounters. Two potential reasons for this include that the larger groups simply are producing more whistles and/or their whistle rate per individual is higher. We are currently tesing this hypothesis by identifying the number of calls detected relative to the estimated number of individuals in all groups. In either case, smaller groups of sound sensitive MHWs, similar to those sighted during this study period, will likley be more difficult to acoustically detect and classify.

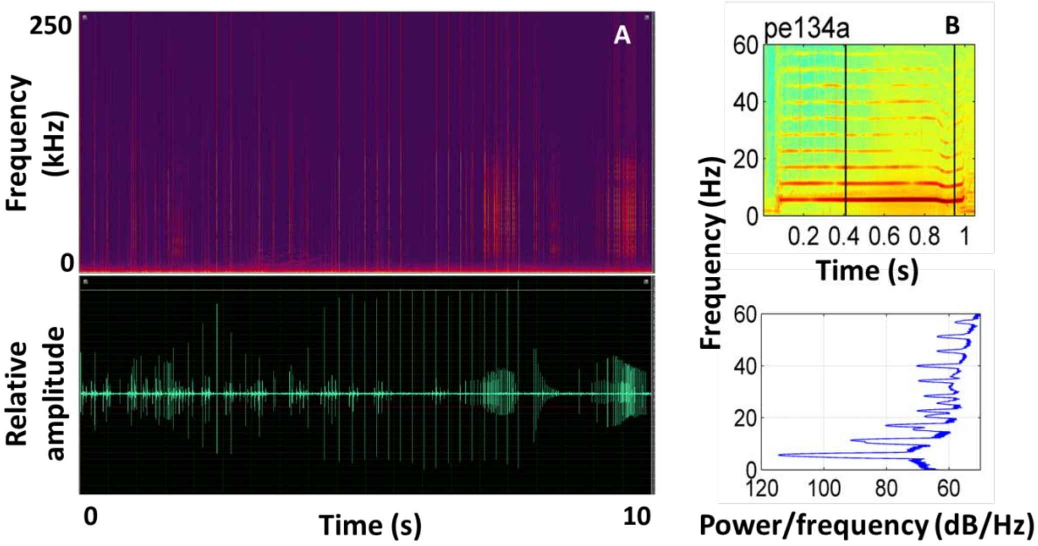

Figure 2. (A;Top) Spectrogram of MHW broadband clicks showing significant energy up to the full 250 kHz limit. The greatest energy is contained between 12-110 kHz. (Bottom) The waveform of those clicks showing sequences from at least two animals. Recordings were made with the DMON towfish. (B) Spectrogram (top; sampling rate 240 kHz, FFT size 2048 samples, 50% overlap) and power spectral density estimate (bottom) of a characteristic call from one of the DTAGged MHWs. Vertical black lines denote the 95% energy duration of the call.

While the whistle rate of the smaller groups appears relatively low, we did record a large number of echolocation clicks (Figure 2A). These clicks had significant broadband energy. The ability of the DMONs and DTAGs to record broadband sound (up to 250 kHz) allows us to quantify some parameters signals (taking into account that many signals are off-axis). Previous measures of MHW signals have been limited to sounds < 20 kHz, thus missing substantial acoustic energy. Thus, our technique is allowing for novel assessments of MHW clicks. Because we deployed the DAWG and towfish with multiple other species, we plan similar analyses with those data as well.

Compiling these data and work from our previous field sessions, we are currently addressing the variablity within MHW whistles. We are focusing on two initial aspects. First, we are descriptively definining all single calls by standard variables including start, end, min, max, peak, centroid frequency, and whistle duration with the goal of assessing broadband call stucture and variablity (Table 2). Substantial variablity appears to exist suggesting that the spectral and temporal characteristics of calls may vary by call type. Thus, the second analysis method is to categorize the calls by call type (Figure 2B) in order to evaluate whether the spectral and temporal characteristics of the call are significant predictors of call type. We suspect that they will be. Call type is being identified categorically by a series of independent observers.

Table 2. Preliminary descriptive statistics of whistle parameters recoreded on the DTAG.

	Call duration (s)	F_{start} (kHz)	F_{end} (kHz)	F_{min} (kHz)	F_{max} (kHz)	F_{peak} (kHz)	$F_{centroid}$ (kHz)	$SL_{95\%EFD}$ (dB re 1 uPa^{2}s)
Mean	0.66	3.36	8.74	2.44	13.58	8.83	10.73	126.8
Std. Dev.	0.37	3.75	4.33	2.05	3.76	3.13	7.79	8.2

We also addressed FKW acoustic signaling and shading through an experiment conducted at the University of Hawaii's Marine Mammal Research Program. In a series of experiments we placed the DTAG on a stationed , trained FKW. A whistling or clicking dolphin was moved relative to the FKW. The dolphin was signaling on command. The DTAG was placed at different locations on the FKW head and body. The work evalutes effect of DTAG placement on signal detection and how received sound levels are influenced by, and perhaps heard differently, due to acoustic shadowing of the receiver's (the FKW's) body. The results are complex and analyses are still underway, although we see several initial trends. For example, whistle energy flux density (EFD; dB re 1 $\mu Pa^2 s$) decreases somewhat (4 dB) at an animal 90°, and 1 m from the signaler. But EFD decreases substantially (almost 20 dB) on the other side of the animal. Further, EFD levels vary consistently based on signaler location relative to the receiving FKW. These changes in levels likely provide cues for localization during communication.

We are also examining the acoustic recordings (DTAG and DMON) of the additional species we sighted. This includes assessing call rates, call detection rates, and received energy levels of pantropical spotted dolphins in groups that are associated (or not associated) with fishing vessels. For the tag deployments, we had a steep but effective learning curve. The first tag did not attach well, but we vastly improved with each attempt and deployment; three of the last four tags attached for the pre-set deployment durations and those last four all recorded for mulitiple hrs. We are combining all three data sets (tags and DMONs) for this analysis. The hypothesis is that whistle rates may change when dolphins associate with fishing boats, and that these animals receive significant energy flux density levels (dB re 1 $\mu Pa^2 s$) over the long duration they are exposed to vessel noise. We have data from five DTAGs deployed on this species (> 17 hrs of recordings). The bioacoustics data set is novel in itself, but it also provides a substantial proof-of-concept for the DTAG v3 attachment to small odontocetes. This is a significant advancement the study of small odontocetes.

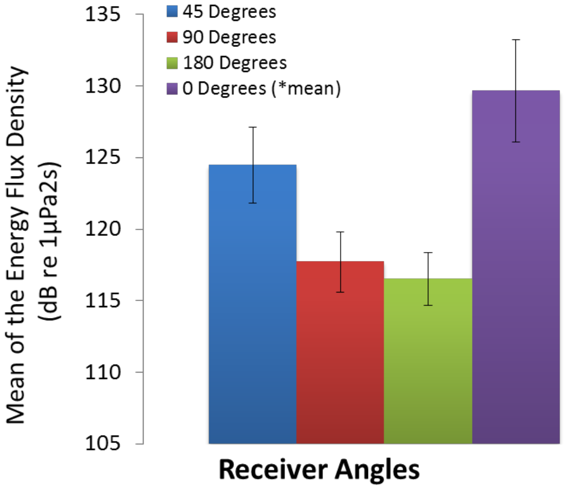

Figure 3. Comparison of whistles EFD recorded on the DTAG, when the tag was placed on the lower jaw (side of jaw facing signaling dolphin) of the receiver (FKW). The dolphin signaler was then moved to three different angle positions in reference receiver (45, 90, & 180 degrees). Data are compared to the mean EFD of whistles recorded from the on axis hydrophone (0 degrees from the signaler).

We collected several hrs of broadband recordings (via the DMON towfish) from rough-tooth dolphins (*Steno bredanensis*). Like many Hawaiian odontocetes, sounds of rough-tooth dolphins are not well categorized, especially for Pacific or Hawaiian waters. Applications of certain species-specific acoustic detector-classifiers have generated some controversy in part due to uncertainty surrounding rough-tooth dolphin signals (Au et al. 2013). Our far-field recordings provide a unique data set to characterize the sounds produced by this species.

We are also using the acoustic records and Cascadia's long history of pilot whale genetic and photo identification to examine potential call types associated with groups or individuals. This work is being led by a Scripps Institute of Oceangraphy graduate student.

IMPACT/APPLICATIONS

This research will provide novel and necessary baseline data on the bioacoustics of two cetacean species of concern which occupy waters frequently used in U.S. Naval training operations. This work seeks to 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, recently listed as Endangered, 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. Additionally, this work seeks to quantify the bioacoustic signals and soundscapes of several additional overlapping species. Five substantial tag attachments to small, pelagic delphinids suggests we can efficiently address the behavior of species for which basic biological information is often lacking; but, due to large group sizes, are species which comprise large portions of the Navy marine mammal takes. 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: Beta Testing of Persistent Passive Acoustic Monitoring; Award Number: N000141010381. Provided initial DMONs for field use and data collection.

WHOI-Marine Mammal Center: Look Who's Talking: Identifying the bioacoustic signals of sound-sensitive cetaceans and new applications for the DMON. Develping a towfish and the DAWG drifter for the DMON.

REFERENCES

Aschettino JM, Baird RW, Webster DL, Schorr GS, McSweeny DJ, Huggins JL, Mahaffy S (2009) Melon-headed whales (*Peponocephala electra*) in Hawaiian waters: A look at population size and structure. 18th Biennial Conference on the Biology of Marine Mammals, Quebec City, Canada

Au WWL, Giorli G, Chen J, Copeland A, Lammers M, Richlen M, Jarvis S, Morrissey R, Moretti D, Klinck H (2013) Nighttime foraging by deep diving echolocating odontocetes off the Hawaiian islands of Kauai and Ni'ihau as determined by passive acoustic monitors. J Acoust Soc Am 133:3119-3127

Baird RW, Schorr GS, Webster DL, McSweeney DJ, Hanson MB, Andrews RD (2010) Movements and habitat use of satellite-tagged false killer whales around the main Hawaiian Islands. Endangered Species Research 10:107-121

HONORS/AWARDS/PRIZES

Invited Conference Presentations

1. Mooney, TA, Kaplan, M, Baird, R, and Partan, J. DTAGs, DAWGs, and Towfish: Using multiple recording platforms to characterize odontocete acoustic space. 166th Meeting of the Acoustical Society of America, San Francisco, CA, 2-6 December 2013.

Student Presentations

1. Kaplan, M, Mooney, TA, and Baird, RW. Differences in melon-headed whale (*Peponocephala electra*) whistle characteristics sympatric populations in Hawaii. 20th Biennial Conference on the Biology of Marine Mammals Dunedin, New Zealand, 9-13 December 2013.
2. Milette-Winfree, AJ, Nachtigall, PE, Mooney, TA, Pacini, AF, Kaplan, MB**, Shedd, TG, Smith, AB, Quintos, CT, Vlachos, SA. Using a DTAG to quantify sound level and frequency shadowing of a “receiving” false killer whale. 20th Biennial Conference on the Biology of Marine Mammals Dunedin, New Zealand, 9-13 December 2013
3. Milette-Winfree, AJ, Nachtigall, PE, Mooney, TA, Pacini, A, Shedd, TG, Smith, AB, Quintos, CT, Vlachos, SA. It takes two: The replication of a social interaction to quantify variations in acoustic cues with animal position and head morphology. The 41st Annual Symposium of the European Association of Aquatic Mammals, Nürnberg, Germany, March, 2013. **Best Student Poster**