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Behavioral Responses of Naïve Cuvier's Beaked Whales in the Ligurian Sea to Playback of Anthropogenic and Natural Sounds

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LONG-TERM GOALS

The principle goal of this project was to study responses of Cuvier's beaked whales (*Ziphius cavirostris*) to MFA sonar signals. Secondary goals included conducting a killer whale playback that has not been preceded by a sonar playback (as in Tyack et al. 2011) and collecting more baseline data on Ziphius.

OBJECTIVES

This investigation set out to safely test responses of *Ziphius* to sonar signals and to determine the exposure level required to elicit a response in a site where strandings have been associated with sonar exercises and where the whales seldom hear sonar.

APPROACH

The University of St Andrews was the prime grantee for this project. The PI, Peter Tyack, was ultimately responsible for the project. Leigh Hickmott, also supported through the University of St Andrews, acted as the cruise science lead when the PI could not be on board. The Woods Hole Oceanographic Institution (WHOI) was subcontracted to provide DTAGs and associated supplies, to organize the logistics of the cruise including vessel, room and board on land, and to hire expert beaked whale observers. The Centro Interdisciplinare di Bioacustica e Ricerche Ambientali (CIBRA) supplied the towed hydrophone arrays, amplifiers, and computers required for passive acoustic monitoring of *Ziphius* clicks, along with skilled passive acoustic monitoring personnel. Massimiliano Rosso (CIMA Research Foundation) provided detailed life history data for the Ligurian *Ziphius*, collated real-time sightings data from ferry surveys and arranged for the CIMA vessel 'Leon Pancaldo' to aid our search for *Ziphius* during the cruise.

Our group has conducted several Dtagging cruises for *Ziphius* in the Ligurian Sea, with the first whale tagged in 2002. During 2003-2004, seven *Ziphius* were tagged with attachment durations of up to more than 15 hours (Tyack et al. 2006). The Ligurian Sea site selected for this project has provided an excellent data set of baseline data (even better than that available for Blainville's beaked whale, *Mesoplodon densirostris*, at AUTEC) for the successful statistical analysis of responses to sonar provided in Tyack et al. (2011), and the value of additional baseline data has been a goal of this project

as well. The month of June was chosen for the field effort to take place, based on both historical *Ziphius* sighting and weather data to provide the highest number of tagging and playback opportunities.

A 24 m schooner, the RV Aleph was employed as the principle research vessel, suiting the experimental requirements well. The Aleph was capable of housing a scientific crew of 10, tow and deploy a tagging boat (RHIB with a 25Hp 2 stroke) and house and deploy both an acoustic array and playback equipment. Importantly the vessel was also able to remain at sea for multi-day periods during the field effort. **Playback Equipment** - The acoustic signals for the sound playbacks were provided by an Olympus LS-11, a Rolls MX22s mini mix preamplifier and a Crown CDi power amplifier. A Lubell LL-1424HP was selected for the source, with a useful frequency range of 200Hz-9 kHz, a maximum SL of 197 dB re 1 µPa @1m @ 600Hz with 80 Vrms applied, and a nominal impedance of 8 ohms. The small dimensions (16.5" x 16.5" x 16.5") and transducer cage made the Lubell an effective and easy to deploy sound source that could be towed at up to 2 knots. **Acoustic array** – the CIBRA array consisted of two wideband, high sensitivity and low noise dipole towed arrays, deployed in parallel from the sides of the vessel. The four sensors are placed at the vertices of a virtual square 8 m wide. Analog signals were filtered and digitized at 192 kHz sampling rate, acquired and displayed on a PAM Workstation using SeaPro software developed at CIBRA. **Whale tag** - The DTAG v2 is a miniature sound and orientation recording tag developed at WHOI. The tag contains a VHF transmitter used to track the tagged whale during deployment and to retrieve the tag after release. DTAGs record sound at the whale as well as depth, 3-dimensional acceleration, and 3-dimensional magnetometer information. DTAG audio was sampled at 192 kHz and other sensors at 50 Hz, allowing for a detailed reconstruction of whale behavior before, during, and after sonar transmissions. The tag is attached to the whale with suction cups using a 7m hand-held carbon fiber pole. **Tracking and data collection** - To visually search for animals in the search phase, and to observe the behavior of the animals during tagging and tracking, a marine mammal observer platform was installed on the deck of the Aleph. Observers scanned with naked eye and 7 X 50 binoculars. This platform was be equipped with a computer running the behavior logging program LOGGER and a VHF digital direction finder system for tracking the tag.

WORK COMPLETED

A one-month cruise took place in June 2012, based from the port of Savona, Italy (Fig. 1). The vessel proved excellent for showing that at-sea playback experiments can be conducted from small cost-effective platforms. The small well-trained crew was able to track groups of *Ziphius* over long periods, smoothly transitioning from visual to acoustic tracking and *vice versa* as whales undertook foraging dives. The small size of the Lubell source and regular drills in deployment and recovery meant the source could be deployed in less than 1.5 minutes and recovered within 30 seconds. The Lubell's size and housing cage also meant it was possible to safely tow the source at operational speeds (2 knots) while acoustically tracking foraging *Ziphius*. This towability was a necessary requirement as Ziphius may travel over 1 km while foraging, and the vessel must follow the whales to remain within acoustic range and near enough for tagging/playback. The small crew and vessel size lent themselves to an ease of communication within all phases of the experimental design. Acousticians, source technicians, visual team members and helmsman could all communicate and relay information to the chief scientist directly without the need for radios or other devices. This facilitated focal follows and supported smooth playback operations (e.g. immediate shutdown or source deployment procedures), which are critical for playback trials.

The CIBRA passive acoustic monitoring system, originally designed for large oceanographic ships (e.g. the NRV Alliance in MED09), was re-designed to meet the power, space and personnel constraints of small vessel use. The re-designed system was able to provide a real-time navigation mapping and localization display for beaked whale clicks. All four audio channels were acquired and processed in pairs for Time Delay of Arrival (TDOA), both on longitudinal and lateral axes, providing fore-aft and right-left information. The system, which is based on the integration of machine and operator (rather than pursuing a fully automated system), proved highly successful at acoustically tracking animals. The system proved easy to deploy, monitor and recover, which allowed the small vessel to maneuver unimpeded during all experimental phases.

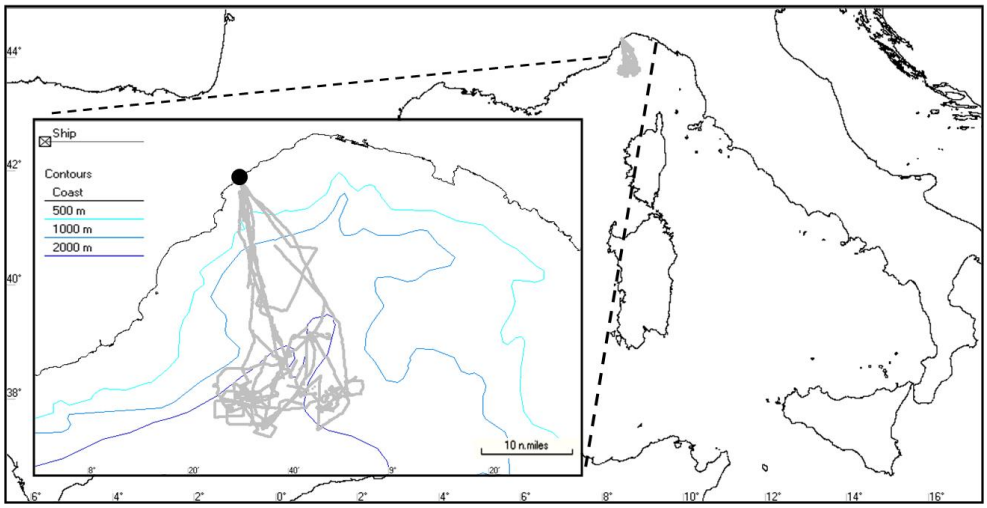

Figure 1. Map of Mediterranean Sea with expanded inset of the Ligurian Sea study area. Black spot indicates Savona, Italy the experiment's homeport. The grey lines indicate the survey effort conducted during the cruise.

RESULTS

Effort – Unseasonably unstable weather limited the number of operational days because of high wind speeds. During the 12 workable sea days, more than 1050 km and 161 hours of on-effort survey were completed (Fig. 1) and acoustic monitoring was undertaken at all 'on-effort' times when in water depths greater than 500 m. The survey effort generated 234 sightings of four cetacean and one turtle species (Table 1) and 2746 photo-ID images were collected of three cetacean species (*Ziphius*, striped dolphin (*Stenella coeruleoalba*) and fin whale (*Balaenoptera physalus*).

Table 1. Table of species recorded, with the number of encounters per species and mean group sizes and ranges.

Species	No. Encounters	Mean Group size (range)
Cuvier's beaked whale *Ziphius Cavirostris*	21	1.9 (1 - 4)
Striped dolphin *Stenella coeruleoalba*	63	9.6 (1 - 50)
Fin whale *Balaenoptera physalus*	59	1.3 (1 - 4)
Sperm whale *Physeter macrocephalus*	1	1 (1)
Unidentified dolphin species	61	8.7 (1 - 45)
Unidentified large whale	12	1.3 (1 - 3)
Loggerhead turtle *Caretta caretta*	17	1 (1)

Ziphius sightings - 28 *Ziphius* (some of which may be resights) were observed during 21 separate sightings (Fig. 2), with a mean group size of 1.9 individuals (Table 1). The distribution of *Ziphius* during the cruise differed from sighting locations during the previous field efforts (2002 – 2007). Known preferred habitats (based on historical sighting data) were within 18 km from shore in water depths between 1000 and 1500 m. This planned primary field site could be reached on the Aleph in less than 1.5 hours from the home port of Savona. However, when these areas were searched, no visual or acoustic detections of *Ziphius* were made. Sightings reported by CIMA during the study and our own efforts forced our search further offshore, where animals were eventually found in water depths greater than 2000 m and at distances of over 55 km from shore. This distribution shift had a profound influence on the experimental plan, as our efforts were modified from planned single day efforts, to multi-day cruises requiring detailed advance planning and provisioning. This significant change meant search effort was most effective with the Aleph remaining in prime offshore habitat for longer periods and making fewer trips to shore.

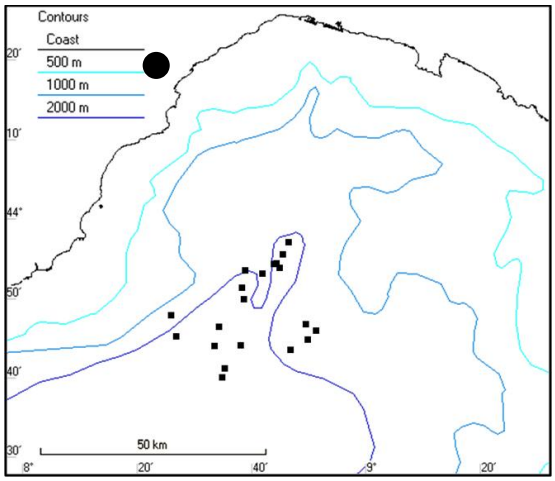

Figure 2. A map of 21 Cuvier's beaked whale sightings distributed around and beyond the 2000 m depth contour. The large black circle on the coastline indicates the port of Savona.

Ziphius focal follows – fifteen focal follows (where *Ziphius* were successfully tracked over one or more shallow or deep foraging dives) were completed. Focal follow durations ranged from 16 minutes to 8 hours 12 minutes, with a mean of 2 hours 35 minutes. On ten occasions, *Ziphius* were visually

observed commencing foraging dives, successfully tracked acoustically and relocated by the visual team on returning to the surface. Eight focal follows contained one complete foraging dive sequence and the two longest follows (8 hrs 12 mins and 7 hrs 47 mins) encompassed two foraging dive cycles. Long focal follows are necessary for playback experiments and the ability to conduct such long focal follows with a small expert team and vessel was an excellent achievement.

Photo-ID - It was possible to collect high quality photo-ID images during eight *Ziphius* encounters and twelve animals were successfully photo-documented: five adult females, three immature, two juveniles, one adult male and one subadult male. Of these twelve, six of the animals were recaptures seen in previous years (Table. 2). *Ziphius* data are difficult to collect and these data points and resights have made valuable additions to the habitat preference and population modeling data sets being collated by Massimiliano Rosso at CIMA.

Table 2. Life history data for six photo-identified Ziphius.

Animal ID	Age Class	Date Enc.	First Enc.	Last Enc.	Estimated Age
110804	Unk. imm.	09-Jun-12	04-Aug-11	04-Aug-11	> 2
20000	Adult female	15-Jun-12	12-Mar-02	21-Jun-06	> 15
990716	Adult male	17-Jun-12	16-Jul-99	16-Mar-05	> 30
30900	Adult female	23-Jun-12	10-Sep-03	16-Sep-11	12
70721	Adult female	23-Jun-12	21-Jul-07	21-Jul-07	> 8
60910	Sub-adult male	27-Jun-12	07-Sep-06	15-Aug-11	9

Acoustic survey effort - 15 acoustic contacts with Ziphius (6 of which were acoustic detections that preceded visual contact) were made during the cruise, resulting in almost 6 hours of recorded vocalizations. On all but two occasions, the CIBRA personnel were able to track vocalizing animals, direct the Aleph to maintain proximity with the focal animal and direct the tag boat with good approximation to the next surfacing area. The CIBRA system proved to be very effective in detecting and tracking beaked whales from a moving vessel. Preliminary analysis of the acoustic data has highlighted two click sequences produced by a group of three *Ziphius* on the 23rd June when joining together at the surface. Such surface clicking behavior has seldom been previously documented in *Ziphius*. If further analysis confirms these are surface clicks produced by this species, these data may prove invaluable in building a more clear understanding of *Ziphius* social and acoustic behavior. Recordings of two other species (striped dolphins and sperm whales) were also made during the cruise.

DTAG effort – The tag boat was launched on thirteen occasions to attempt tagging, covering 123 km during focal follows and tagging efforts. Three tagging attempts were made, with one successful tag deployment on an adult male *Ziphius* (Zc12_169a, animal ID 990716). The tagged whale made seven foraging dives during the tag deployment, foraging predominantly in the middle of the water column, where the average water depth was 2000 m (Fig. 4). The planned playback procedure had to be abandoned as the animal was lost during the focal follow. This was due to the masking of the foraging clicks by a large group of striped dolphins, and the loss of VHF signal from the tag, as it slid blow the waterline during the first foraging dive. Efforts were made to relocate the animal visually and acoustically throughout all day and night hours that the tag was on the animal. It was hoped that if relocated, a playback could have commenced the following morning. Unfortunately the animal was only relocated when the tag detached and could be located using the VHF signal from the floating tag.

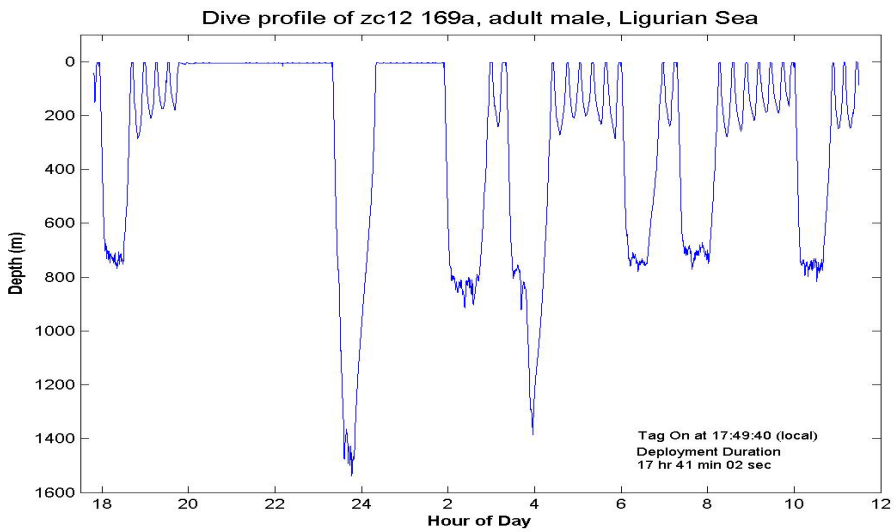

Figure 3. Dive profile of Zc12_169a (animal ID 990716, an adult male). Note the long logging/shallow surfacing periods recorded between 19:30 and 2 AM local time.

This DTAG dataset is considered very important, as the tag recorded prolonged surface periods of logging, in one case, immediately after a deep foraging dive (Figure 3). Such surface periods have been considered possible response mechanisms for exposed animals, with potential risk of decompression, and these data highlight the requirement for caution and detailed baseline data for comparative purposes, before conclusions on the nature of responses to sound exposure are made.

RESULTS

The baseline data collected from the Dtagged Ziphius provided important baseline dive data for an analysis of responses of a Ziphius Dtagged in waters off southern California in response to playback of a naval sonar. No baseline dive data were available for the southern California site. Limited data were available from Hawai'i, but the Ligurian Sea provided the majority of baseline data for this study. Much of these data stemmed from earlier cruises, but the data from this project was also critical.

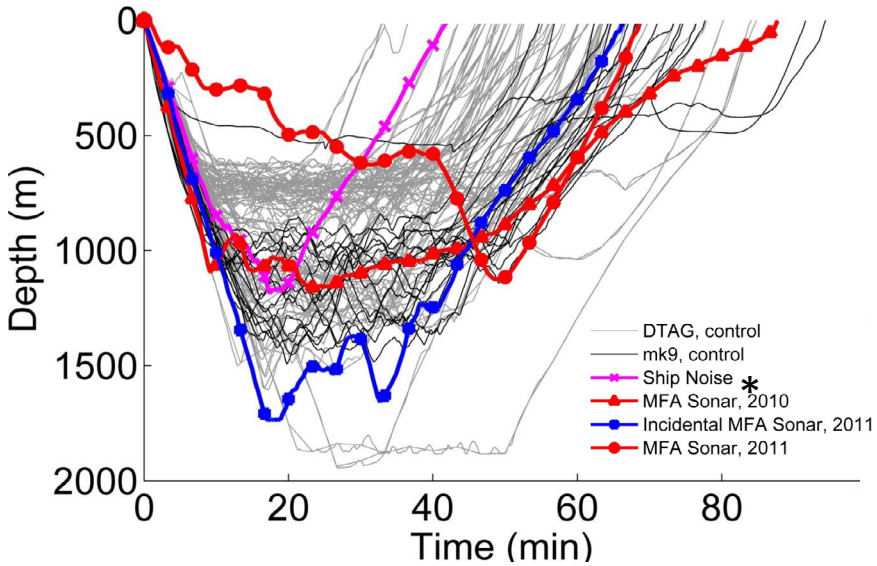

Figure 4. Dive data from exposures to sonar (southern California), ship noise (Ligurian Sea), and baseline data from the Ligurian Sea and Hawaii (gray lines) forming basis for analysis of responses of Ziphius to sonar described in DeRuiter et al. (2013).

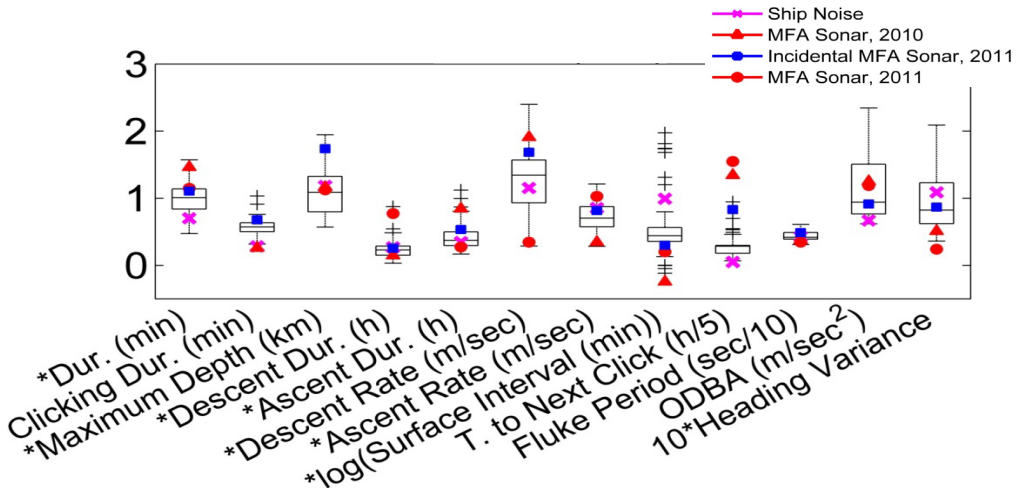

Figure 5. Summary of characteristics of deep dives from tagged Ziphius including exposure and baseline dives.

Both of the sonar exposure dives marked in red in Figures 4 and 5 were longer than all but the few longest baseline dives. The factor for which the exposure dives were the biggest outlier was the time from end of clicking during the exposure dive to the next click. Both exposure dives were marked by unusually long post exposure inter-deep-dive intervals.

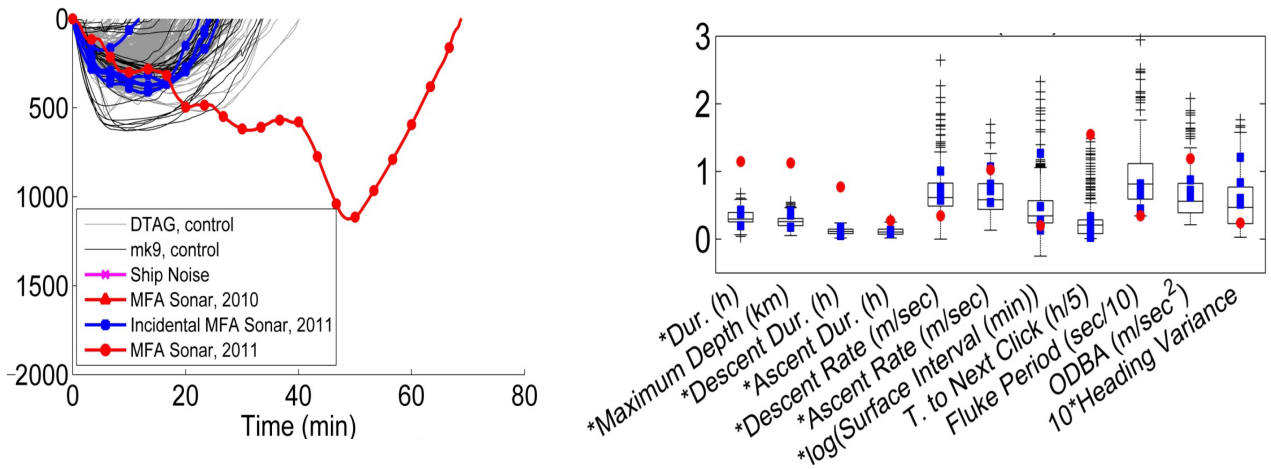

Figure 6. Left: Profiles of shallow dives from tagged Ziphius. Right: Summary of characteristics of shallow dives from tagged Ziphius including exposure and baseline dives.

The Cuvier's beaked whale exposed in 2011 did not echolocate during the CEE dive, making the dive difficult to classify. It matches foraging dives in duration and depth but not dive shape and is unusually long and deep for a silent dive (figure 7). By contrast, shallow dives coinciding with the distant naval exercise were similar to control shallow dives (Figure 6). As can be seen from the figures above, these baseline data formed a critical part of the statistical analysis of responses of Ziphius to sonar described in the DeRuiter et al. (2013) paper.

IMPACT/APPLICATIONS

The small vessel, small expert team approach was well tested and proven during this cruise and although playbacks were not achieved, every aspect of the experimental design was rigorously tested and honed for future efforts. The ability to detect *Ziphius* and conduct long focal follows using a small visual team and the CIBRA array was well proven, providing a good standard for conducting future playback experiments to *Ziphius* from small cost effective platforms. An important research topic for the ONR Marine Mammals and Biology program is to study the responses of beaked whales and other whales to naval and anthropogenic sounds. This study is important for this on several levels: First, the additional baseline data were critical for the analyses of responses of *Ziphius* from the first successful sonar CEEs to *Ziphius*, as published in DeRuiter et al. (2013), secondly, they will continue to be important for projects such as MOCHA, which is developing across-study statistical analyses, and thirdly, an increased understanding of the behavior and acoustic signalling of *Ziphius* during surface intervals in baseline will help us to identify responses to sonar. Our tag data from this project also were used by Barlow et al. (2012) to estimate the trackline g(0) probability for using passive acoustic monitoring to detect *Ziphius*. The use of tag data for estimating critical parameters for distance sampling is of growing importance for monitoring marine mammals and estimating their density and abundance (Marques et al. 2012).

RELATED PROJECTS

BRS Socal project funded by N45 – the environmental readiness division of the US Navy.

MOCHA – Multi-study ocean acoustics human effects analysis, ONR award number N000141210204: use of the DTAG data to contribute to baseline information and models for analyzing behavioral responses to sonar. CIMA Research Foundation – collaboration with Dr. Massimiliano Rosso, providing photoID data and contributing to CIMA's efforts to establish the conservation status of Cuvier's beaked whale (*Ziphius cavirostris*) in the Mediterranean Sea.

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