Conduct Research on the Foraging Ecology of Beaked Whales in Hawaiian Waters

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LONG-TERM GOALS

The overall goal of our research is to understand beaked whale foraging and to learn how to alleviate acoustic encounters between Navy assets and beaked whales and other deep diving odontocetes. Understanding of the characteristics and dynamics of the prey field is critical in understanding the foraging behavior and life cycle of beaked whales. The movement patterns of any animals are strongly affected by the availability of food resources, so in order to understand the foraging behavior of beaked whales, the behavior of the prey, the oceanographic conditions affecting the presence of the prey and how the whales interact with the prey field all needs to be better understood.

OBJECTIVES

The goals of our research can be summarized as follows:

1. estimate the three-dimensional spatial extent of potential prey field
2. collect synoptic data of beaked whale foraging on the prey field
3. determine the taxa composition of the prey field
4. estimate the size and density of the micronekton in the prey field
5. relate volume scattering coefficient with the density of micronekton in the prey field
6. correlate relevant oceanographic parameters with the presence of the prey field

APPROACH

Beaked whale research in Hawaii has been conducted mainly in the Kona coast of the island of Hawaii and there are an abundance of beaked whales along this coast line (Baird et al., 2006). The mountains of Mauna Kea and Mauna Loa are instrumental in providing a lee so that this area is usually very calm and easy to work in. This is a one-year feasibility study along the Kona coast in areas where Baird et al have previously attached TDR tags on beaked whales. Differences in variables such as the characteristics, dynamics, density, diurnal variations of the prey field and how they relate to the presence of beaked whales will be examined. We propose to use three main techniques and tools to determine the distribution and abundance of the prey field of beaked whales, to understand the relationship of beaked whales and the prey field and to understand how beaked whales interact with the prey field. The three tools that will be used in this study and the manner in which they will be used and the type of data they will collect are enumerated below.

1. The first tool will be at least three of EARs (operating at 80 kHz sample rate) that will be deployed in the study area at depths of 1 km. The EAR data will provide a good indication of the diurnal foraging pattern in each area and also indicate which of these areas beaked whales tend to frequent the most. The EARs will be used during the entire study.

2. The 38 and 70 kHz versions of the Simrad EK-60 scientific echosounder will be used to provide across slope and along slope examination of the prey field. The acoustic volume scattering along the survey tracks will be determined and related to density estimate obtained with the profiler discussed in the next paragraph. We will start of with rectangular transects with long legs nearly parallel to shore and in water depths between 700 and 1500 m. Isobaths in the Kona coast of the Big Island tend to follow the shape of the shore line.

3. The third tool will be a specially fabricated profiler (similar to one designed by Frey et. al, 2011) to investigate the composition, density and the characteristics of the micronekton in the deep layers that beaked whales forage on. The key instrument of the profiler will be the Didson high resolution imaging sonar and a low-light video camera system. A schematic of the profiler is shown in Fig.4 along with examples of Didson images. From the Didson images, the size and density of micronektons can be determined. One Didson model is rated to 1,000 m depth and can be powered by batteries on the profiler with the output (images) fed directly to a digital video recorder which will store the images on a laptop disk. An FM signal controlled by a depth sensor will be fed to the audio channel. The low-light Remote Ocean Systems (ROS) Navigator camera will be used to obtain video images of the prey field. This camera provides both *high resolution* (570 TVL) and *exceptional low-light-level sensitivity*, (3.4 x 10^{-4} lux face plate sensitivity). The camera will be directed in the same direction as the Didson to examine similar volumes of water. High resolution sonar images will be collected before the light is turned on and continue while the light comes on to provide information on how artificial light may affect these deep organisms. An infared led array will also be used to provide a light source outside the visual range of most organisms. The profiler will be constructed during the first year of this study and will be used during latter half of the first year and in the second and third years.

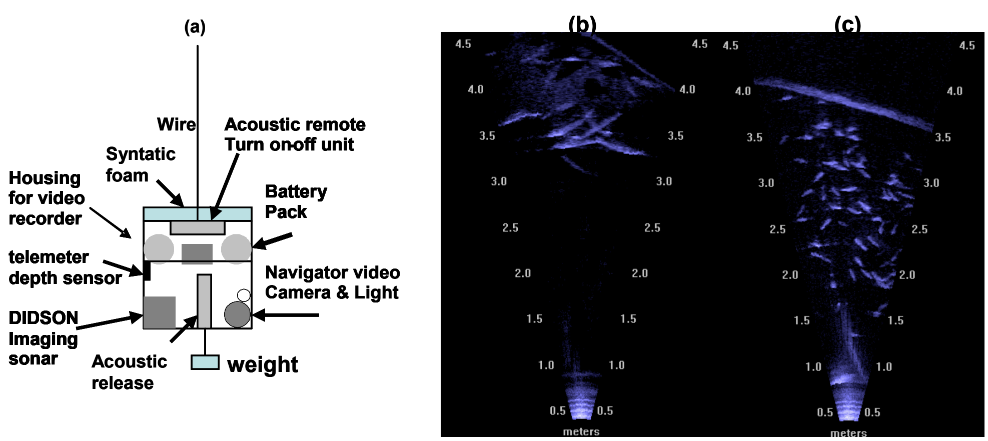


Figure 1. (a) schematic of a profiler to examine the micronektons in the deep layers that beaked whales forage in, (b) DIDSON images of pink snappers having lengths of (b) 38 – 50 cm, (c) 10 – 15 cm.

WORK COMPLETED

A. Initial EAR Deployment

Three EARs were deployed off the west side of Hawaii Island at the locations shown in Fig. 2. The EARs were deployed at approximately 700, 800, and 800 m, from north to south respectively. The duty cycle for each EAR was 30 second recording every 5 minutes. A short deployment period (Feb 18 – May 8, 2012) was chosen so that an initial examination of the data could be done. The M3R (Marine Mammal Monitoring on Navy Ranges) software were used to analyze the data. M3R can identify the biosonar signals from short-finned pilot whales (Globicephala macrorhynchus), sperm whales (Physeter macrocephalus), Risso's dolphins (Grampus griesus) and two species of beaked whales, Blainville's beaked whales (Mesoplodon densirostris) and Cuvier's beaked whales (Ziphius cavorostris). The energy-ratio mapping algorithm developed by Dr. Holger Klinck was also used to detect beaked whales.

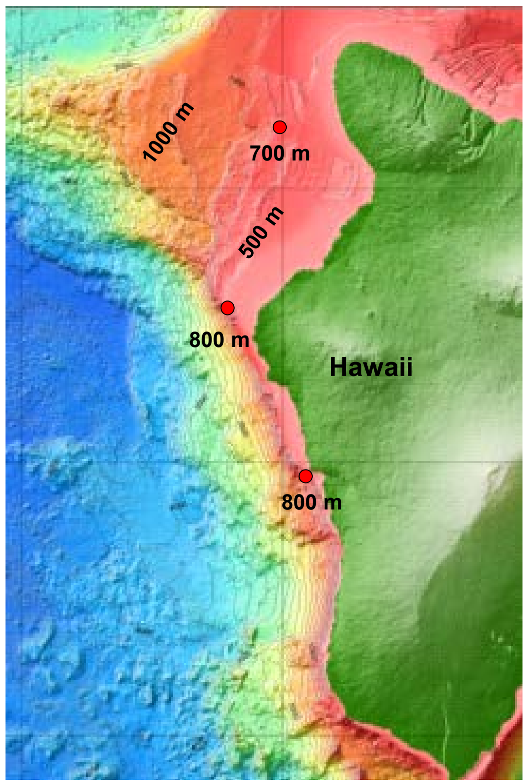


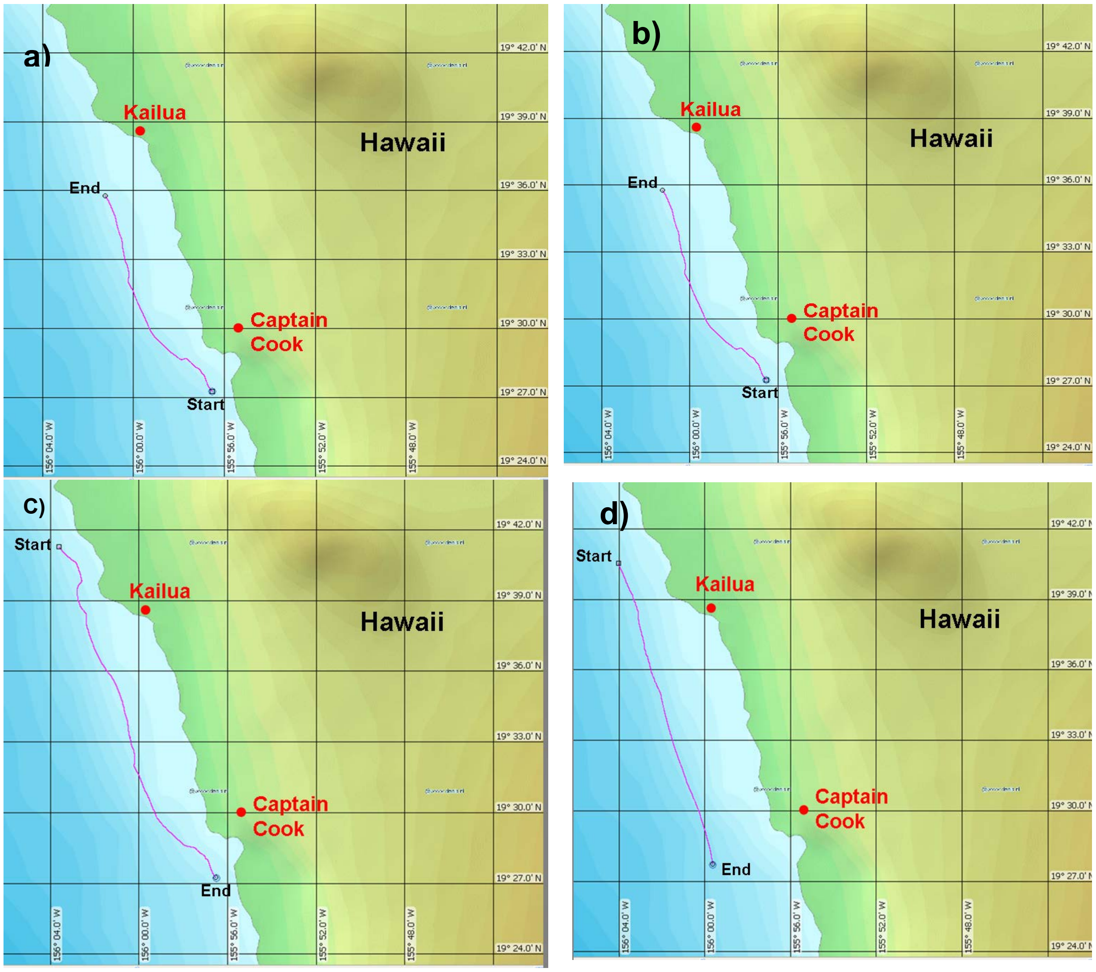
Figure 2. EAR locations on the west side of Hawaii Island

B. Initial Echosounding Survey

An echosounding survey was conducted for five days, July 9-13, 2012. The survey was done with two transects, one just shoreward of the two southern EARs (shallow transect) shown in Fig. 2 following the shoreline from one EAR location to the other at a constant bottom depth of approximately 600 m (Fig. 3 a and c).

C. Construction of profiler

The construction of the profiler containing a high-resolution sonar, video camera and oceanographic instrument is slowly coming together. A photograph of the partially constructed profiler is shown in Fig. 4. Syntactic foam will be attached to the top portion of the profiler to provide



c

Fig. 3a-d. EK-60 survey lines. Fig. a and c are the shallow transect with depth varying from 500-700m. Fig. b and d are the deep transects with depth varying from 1100-1300m. Fig. a and b are the South to North survey beginning south of Captain Cook, HI and ending near Kailua-Kona, HI. Fig. c and d are the North to South survey beginning north of Kailua-Kona, HI and finishing south of Captain Cook, HI.

RESULTS

Preliminary results from EAR

An example of the various detections in terms of the percent of observation periods (OBSP) that contained biosonar clicks from the five different species (Cuvier & Blainville's beaked whales are lumped together) of deep diving odontocetes are shown in Fig. 5. The vertical axis of the graphs in percentage of observation periods (OBSP) in which biosonar clicks were detected. Since each observation period is 30 seconds every 5 minutes, a total of 288 observation periods are available for each day. All the graphs have the same scale so that the relative amount of observation periods with biosonar clicks can be compared relatively easily. Most of the detected clicks were from short-finned pilot whales and sperm whales.

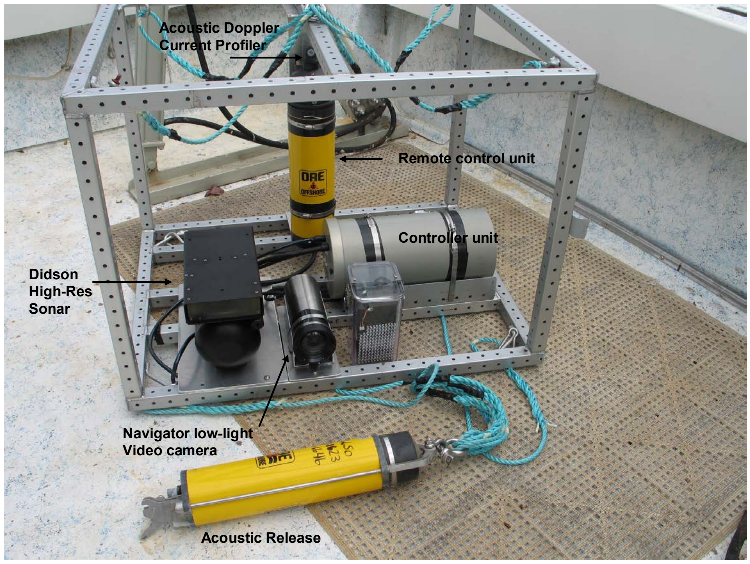


Figure 4. A photograph of the partially constructed profiler. Syntactic foam blocks will be attached to the topside of the profiler to provide floatation and weights will be attached to the acoustic release to provide negative bouyance. Batteries will be contained in the controller unit along with a digital tape recorder.

The percentage of detected clicks from the five species examined are shown in Fig. 6. Approximately 40% of all the observation periods with clicks can be attributed to short-finned pilot whales followed by 23% for sperm whales. The amount of observation periods with beaked whale biosonar clicks was only 6%. The results shown in Fig. 6 are very similar to results obtained at various locations off the island of Kauai in an ONR sponsored study on the use of acoustic monitors in the high Naval activity areas associated with the Hawaiian islands. A rough estimate of the relative abundance of the five species can be determined from the figure if certain critical assumptions are accepted. Some of the major assumptions include the source level of each species and the beam patterns are similar and the different species were diving to approximately the same depths. Unfortunately our understanding of how these different species use their biosonar in foraging for prey is not sufficient to pursue these issues further. However, it would be difficult to argue that the data does not represent within a certain margin of error the relative abundance of the five species. Unfortunately, the magnitude `of the margin of error is not known. Perhaps the most important consequence of the data presented in this figure is the fact the percentage of files with beaked whale signals are very low, the lowest of the five species considered.

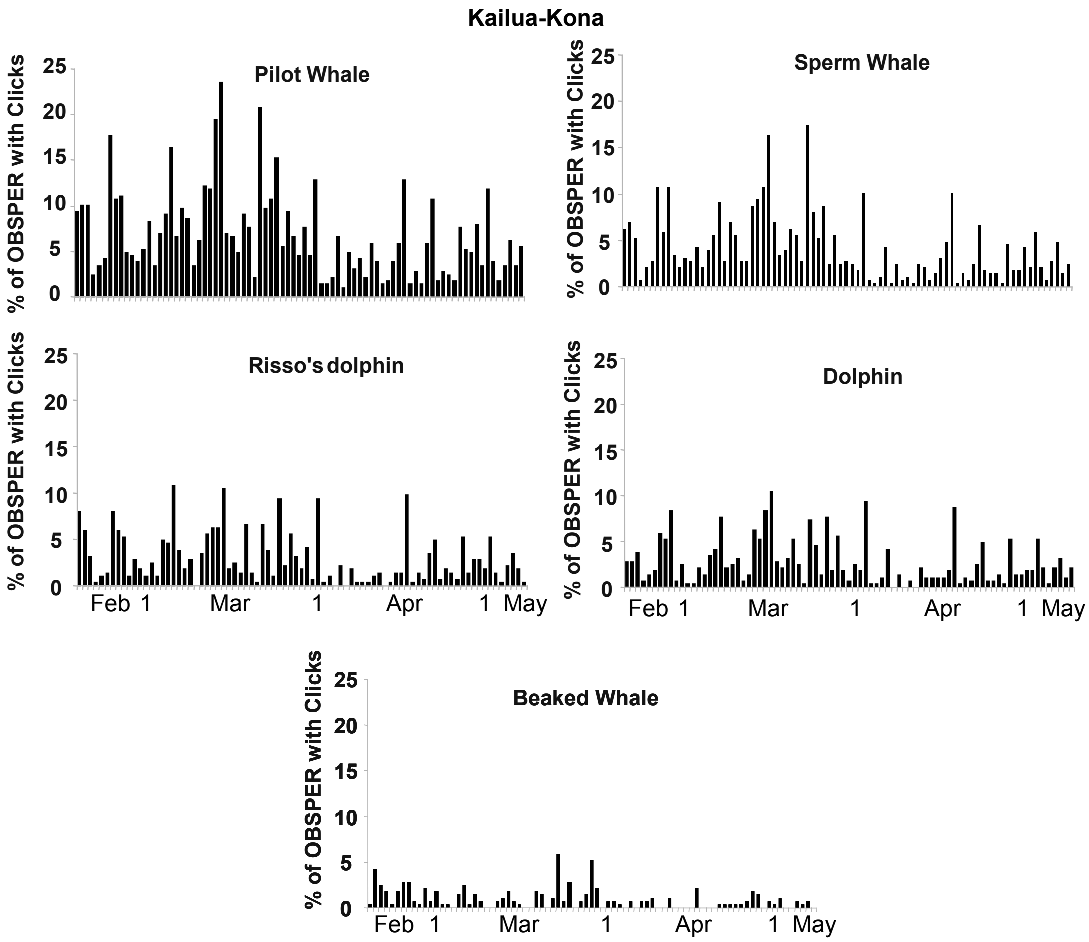


Figure 5. Percent of observation periods in which biosonar clicks were detected from the different species of deep diving odontocetes.

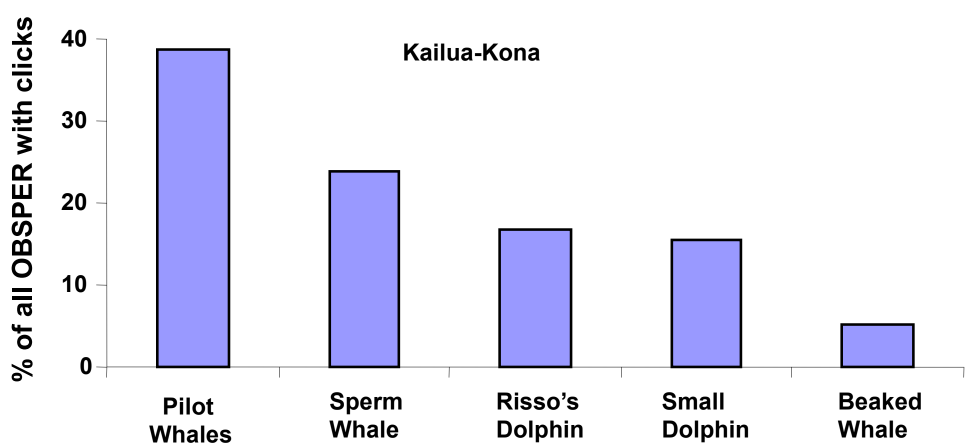


Figure 6. Percent of all observation periods in which biosonar clicks were detected for the different species.

Preliminary Results of Echosounder Surveys

A screen shot of the EK-60/38 kHz and EK-60/70 kHz display are shown in Fig. 7 for the shallow-water transect and in Fig. 8 for the deep-water transect. The data is currently being analyzed. From a "quick look" at the data the following important preliminary assessments can be made:

1. There is a scattering layer at an approximate depth of 500 m.
2. The scattering layer seem to be present at 6:00 pm into the night.
3. Although the 38 kHz EK-60 can penetrate to deeper depths than the 70 kHz unit, the 70 kHz results have finer depth resolution and detect more organisms just below the scattering layer at 500 m. Unfortunately, the 70 kHz unit can only penetrate to approximately 750 m before the display is overcome by electronic noise.
4. It is still not clear why most foraging by deep diving odontocetes occur at night.

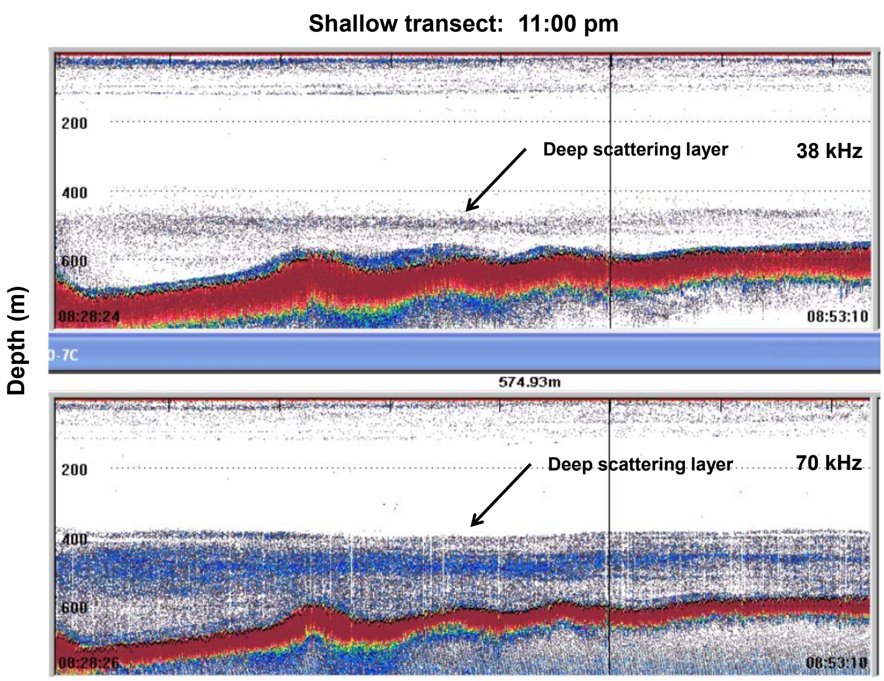


Fig. 7. EK-60 echograms during the shallow-water transect at 11:00 pm. The horizontal distance traveled by the boat was approximately 3 km.

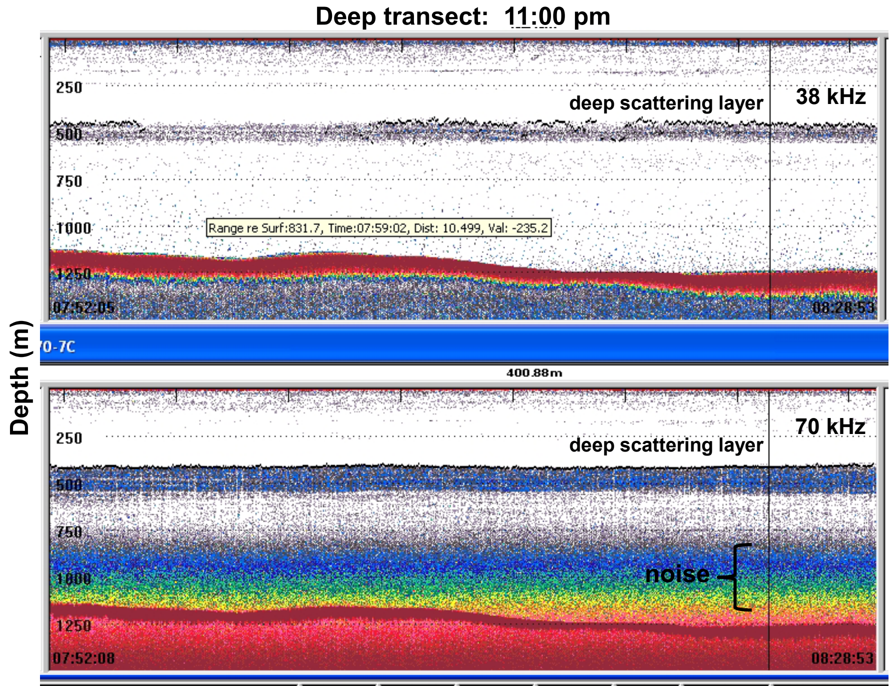


Figure 8. EK-60 echograms during the deep-water transect at 11:00 pm. The horizontal distance travel by the boat was approximately 3 km.

IMPACT/APPLICATIONS

An initial impression of the general foraging patterns of deep diving odontocete has evolved. A general impression of the prey field of deep diving odontocetes is being developed.

RELATED PROJECTS

None

REFERENCES

Baird, R. W., Webster, D. L., McSweeny, D. J., Ligons, A. D., Schorr, G. S., and Barlow, J. (**2006**). "Diving behaviour of Cuvier;s (*Siphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales in Hawai'I." Can. J. Zool. **84**, 1120-1128.

Freg, C.L., Marshall, N.J., and Sherrell, A. J. (**2009**). "Designing Modular Unmanned Landers to Better Observe Life in the Deep Ocean." Sea Technology, **52**, 25-31.

Johnson, M. P. and Tyack, P. L. (**2003**). "A digital acoustic recording tag for measuring the response of wild marine mammals to sound," IEEE J. Oceanic Eng. **28**, 3-12.

Johnson, D.W., McDonald, M., Plovina, J., Domokos, R., Wiggins, S., and Hildebrand, J. (**2008**). "Temporal pattern in the acoustic signals of beaked whales at Cross Seamount." Biol. Lett. **4**, 208-211.

Lammers, M.O., Au, W.W.L. and Aubauer, R. (**2004**). "A comparative analysis of echolocation and burst-pulse click trains in *Stenella longirostris*." In: Echolocation in Bats and Dolphins. Eds. Thomas, J., Moss, C. & Vater, M. University of Chicago Press. pp. 414-419.

Madsen, P. T., Johnson, M., Aguilar de Soto, N., Ximmer, W. M., and Tyack, P. (**2005**). "Biosonar performance of foraging beaked whales (*Mesoplodon densirostris*)," J. Exp. Biol., **208**, 181-194.

Zimmer, W. M. X., Johnson, M. P., Madsen, P. T., and Tyack, P. L. (**2004**). "Echolocation clicks of free-ranging Cuvier's beaked whales (*Ziphius cavirostris*)." J. Acoust. Soc. Am. **117**, 3919-3927.

PATENTS

None