Understanding the Foraging Ecology of Beaked and Short-Finned Pilot 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

The objectives for this past year were:

1. Obtain a preliminary understanding of the biomass environment in which beaked whales and other deep diving odontocetes are foraging by collecting preliminary data with EK-60 scientific echosounder at 38 and 70 kHz
2. Collect PAM data to determine pattern of foraging for beaked whales and other deep diving odontocetes in the Kona coast line

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3. Demonstrate the utility of the DIDSON high-resolution sonar in obtaining biomass images at depth commensurate with typical foraging depth of deep diving odontocetes

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. Funds were not received until January, 2012 and a no-cost extension until August, 2013 was approved to accommodate a "piggy back" participation with a NOAA cruise of the Kona coast in June, 2013. Further funding was not granted until the last quarter of 2014. However the project was barely able to limp along by finding other funding sources for two graduate students and by generosity of the Schmidt Oceanographic Institute who provided 5 days for ship time for further work on the Kona Coast, in February 2014. 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 used 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 used in this study and the manner in which they are used and the type of data they collect are enumerated below.

1. The first tool are three of EARs (operating at 80 kHz sample rate) that were 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 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 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.

The research during the first year geared towards obtaining basic information on the environment that the deep diving odontocetes are foraging in. To this end, the various tools were used almost independently. Having obtained some basic but important information, the project will begin to use the various tools in a more integrated manner. Three stations will be marked off along the Kona coast based on information obtain from the passive acoustic monitoring work done with the EARs. Before each survey field trip, an EAR will be deployed at each station. EK-60 active acoustic surveys will be conducted in the near vicinity of each EAR while visual observers will scan the water for beaked whales, short-finned pilot whales and sperm whales. The DIDSONprofiler will be used to sample the prey field at each station. If marine mammal observers detect whale species of interest, the survey will be terminated and a focal following approach will be taken to survey the scattering layers in the vicinity while the whales are both foraging and not foraging. The DIDSON profiler will be used at appropriate intervals during the focal following process. At the end of the field trip, all the EARs will be retrieved and the data obtained will be coordinated with both the EK-60 and DIDSON data.

The DIDSON profiler will be redesigned so that a low light video camera along with two LED array emitting light in the red spectrum will be used. The profiler will be redesigned for easier use with a small vessel rather than a large ocean going ship.

WORK COMPLETED AND PRELIMINARY RESULTS

A five day survey was conducted off the Kona coast of the island of Hawaii was conducted on February 18-22 abroad the Schmidt Ocean Institute ship the RV Falkor. The ship is an state of the art oceanographic survey ship with the latest active acoustics echosounders and a suite of oceanographic measurment instruments. The ONR project was able to continue with minimum of funding since the availability of the RV Falkor was on a probono basis and although the cruise was a joint School of Ocean and Earth Science and Technology at University of Hawaii and Schmidt Ocean Institute project, most of the objectives of this ONR project were merged into the objectives of the cruise. A map of the stations used in the cruise, which was designated as FK140216, is shown in Figure 1.

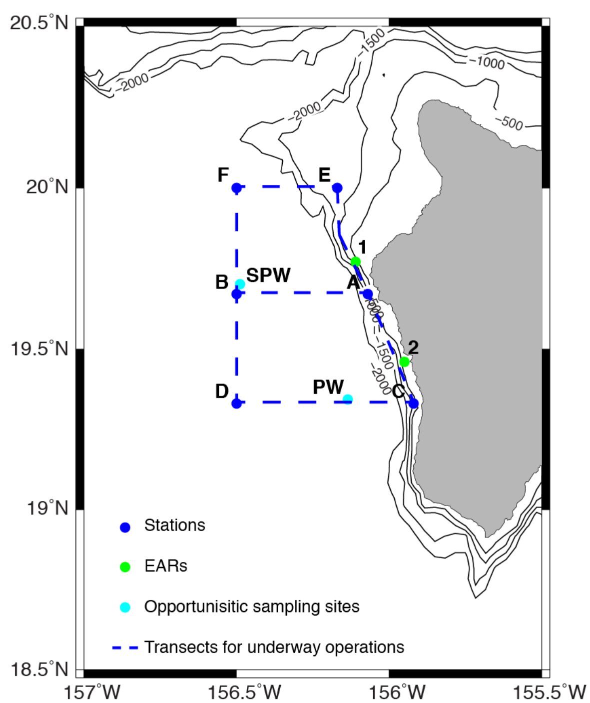

Figure 1. Map of survey area and stations for the FK140216 cruise off the Kona coast Feb 18-22, 2014

The ship was directed along specific transects while the active acoustics were used to obtain echo data on the biomass below the ship. Marine mammal observers were also on the look out for marine mammal sightings. If any deep diving odontocetes including beaked whales, sperm whales and short-finned pilot whales were sighted, the ship was directed over the locations of the sightings. A small boat was launched and a hydrophone deployed overboard to determine if biosonar clicks could be detected as a symbolizing foraging behavior. The biomass over where the animals were examined with the EK-60. If the foraging behavior were detected, the active acoustic files were designated "while foraging." The ship would return to the same area the next day and echo soundings were conducted to measure the biomass when no foraging by whales were observed. The difference in the biomass properties will be compared when marine mammal foraging occurred and when there were no foraging activities. The echo sounding data are presently being analyzed by PhD candidate Adrienne Copeland. Table 1 details the acoustic transects collected during FK140216. All times are reported in UTC.

Table 1: Simrad EK60 transects collected during FK140216

Date	Start time (UTC)	End time (UTC)	Day/Night	Transect
2/16/14	05:18	8:51	Night	F -> E
2/17/14	17:47	20:50	Day	E -> F
2/18/14	06:33	09:02	Night	E -> A
2/18/14	18:44	22:28	Day	A -> C
2/19/14	05:36	07:42	Night	C -> PW
2/19/14	12:06	15:41	Night	C -> A
2/21/14	02:02	04:19	Day	C -> PW
2/21/14	00:52	03:02	Day	E -> EAR1

This section details the DIDSON and CTD operations conducted during the FK140216 cruise off the Kona coast of the Island of Hawaii. During the cruise, nine DIDSON casts were performed together with the CTD. Stations A, C (both during the night and during the day), E (both during the night and during the day), EAR1 (both during the night and during the day), and EAR2 (both during the night and during the day) were sampled during these casts. For these casts, the CTD and DIDSON were lowered to a specified depth for 20 minutes to allow for collection. Normally three depth samples were collected at each site: the deepest depth sampled was below the deep scattering layers identified by the EK60 38kHz frequency; the two shallower depths sampled are within this deep scattering layers. The data from these casts were provided to PhD candidate Giacomo Giorli for analysis and possible future publications.

Five additional CTD casts to 1000 meters were collected at dawn and dusk for Station A, C, and E. This data were provided to NOAA for a comparison with past research collections during 2011 and 2013. Table 2 details all the casts performed during the FK140216 research trip. All times are reported in Coordinated Universal Time (UTC). During some casts, a power issue caused the DIDSON to turn off during operation. This resulted in a failure to acquire data at some of the stations. The casts that were affected by this problem were: C1 (at 670m and 830m), C2 and E1.

Table 2: Vertical casts of FK 140216

Instruments	Station	Date	Start time (UTC)	End time (UTC)	Depth sampled (m)
CTD	E	02/17/14	16:38	17:31	Vertical cast to 1000 m
CTD	A	02/18/14	17:48	18:32	Vertical cast to 1000 m
CTD	C	02/19/14	04:35	05:36	Vertical cast to 1000 m
CTD	A	02/20/14	04:14	05:01	Vertical cast to 1000 m
CTD	C	02/20/14	16:25	17:25	Vertical cast to 1000 m
DIDSON + CTD	A1	02/19/14	05:37	06:53	480, 670, 730
DIDSON + CTD	C1	02/18/14	04:49	06:14	480, 670, 830
DIDSON + CTD	C2	02/19/14	14:41	15:37	500, 650, 760
DIDSON + CTD	E1	02/17/14	14:00	15:07	480, 660, 760
DIDSON + CTD	E2	02/17/14	04:23	05:36	470, 640, 800
DIDSON + CTD	EAR1	02/20/14	14:25	14:45	360
DIDSON + CTD	EAR1bis	02/21/14	02:44	03:04	480
DIDSON + CTD	EAR2	02/20/14	02:10	02:55	480, 570
DIDSON + CTD	EAR2bis	02/21/14	14:24	15:11	480, 630

The CTD samples have not been analyzed. Preliminary analysis of the DIDSON samples has been performed at all the stations sampled. Density of organisms and size distribution were computed for station A1 (Fig. 2). At station A1 mean size of organisms was about 9 cm at all depths. Of interest, there were larger organisms sampled at 730 m. The density of organisms is 1.6 organisms/m3 at 480m. At 630m depth the density decreases to less than 1 organism/m3, and it decreases even more at 730m depth.

At station E2 the mean size of organism detected was about 9 cm at all stations (Fig. 2 left). Organisms larger than 30 cm were detected at 470 m and 640 m. At 470m of depth, the density of the organisms at this station was similar to station A1. However, the density of organisms was lower at station E2 for the deepest depth sampled, 0.4 organisms/m3 at 630m, 0.2 organisms/m3 at 730m (Fig. 2 right).

Plots similar to Figure 2 and 3 have been created for each station successfully sampled with the DIDSON. Future steps will include statistical analysis on the results to understand if differences in length and density of organisms exist between stations, and between depths.

IMPACT/APPLICATIONS

A general understanding of the environment that beaked whales and other deep-diving odontocetes are foraging in is progressively being developed as data from the EARs, Ek-60 echosounders and the DIDSON are being analyzed. There seem to be a deep layer present at about 400 – 800 m deep and about 50% of the layer migrate vertically on a diunal scale. The density of organisms between the bottom part of the deep layer and the bottom is relatively low. Our best understanding is that the prey of beaked whales, mainly squids, can generally be found in this depth regime. The squid probably feed on the bottom portion of the deep layer and deep diving odontocetes typically dive to depth beyond the deep layer to forage. One possible reason for this type of behavior is that the organisms of the deep mesopelagic layer can represent unwanted reverberations for echolocating animals making it more difficult to perform biosonar detection, classification and tracking of prey. Therefore, the density and health of the deep scattering layer is an important entity in the foraging behavior of deep diving odontocetes since the prey of these whales will be affected by the state of the deep mesopelagic layer.

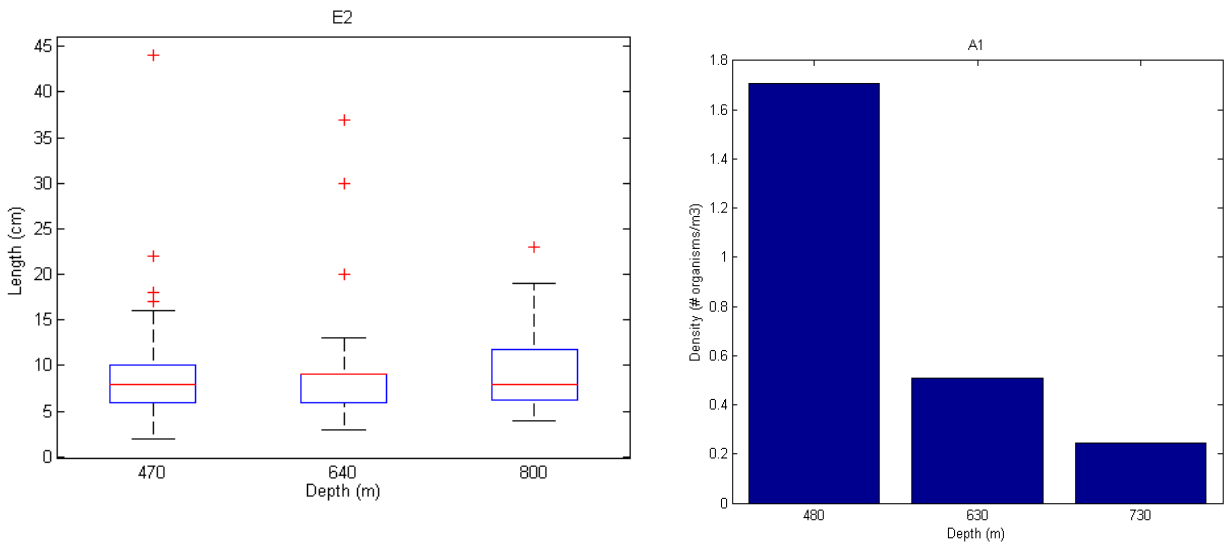

Figure 2: Size distribution (left) and density estimation (right) at station A1

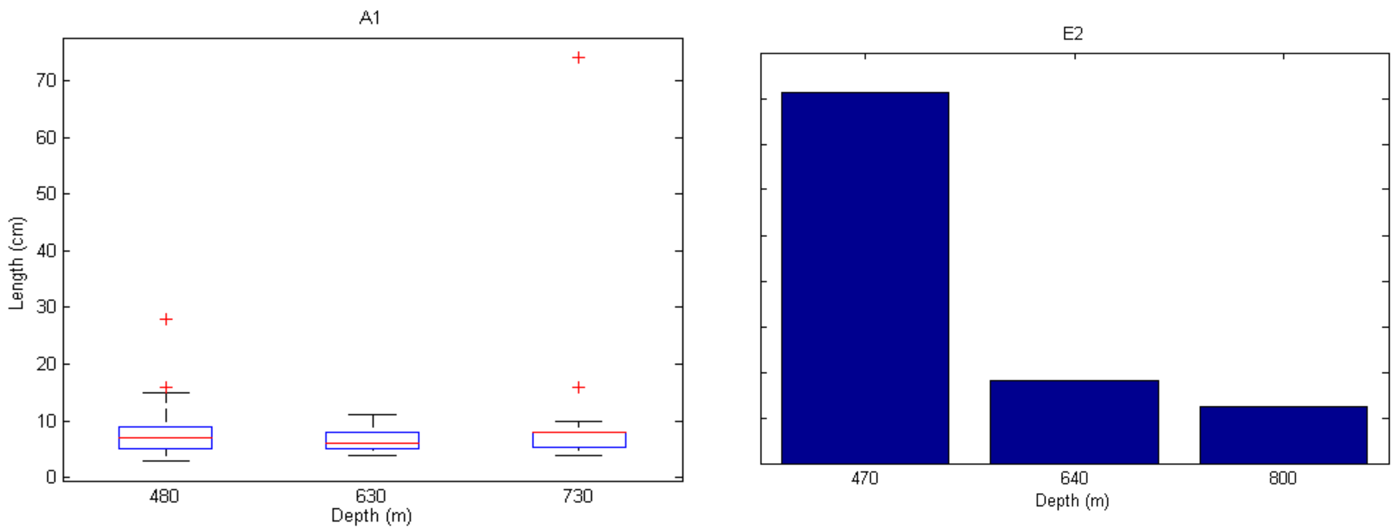

Figure 3: Size distribution (left) and density estimation (right) at station E2.

An important insight obtained during this feasibility phase of this research is the connection between DIDSON and EK-60 data. Fine estimates of the density of organisms in the mesopelagic layer can be obtained with the DIDSON and this data can be used to "calibrate" biomass estimates of EK-60 soundings. Taking this approach will allow for obtaining better esimate of density of mesopelagic organism in the deep layer by EK-60 echosounding surveys. This in turn may provide information of the likelihood of deep diving odontocetes foraging in a particular area of the ocean.

The most important results from this feasibility phase is that the three different type of sensors used in this project can provide the most advanced information that will eventually lead to a much better understanding of the foraging behvior of beaked whales and also other deep-diving odontocetes.

RELATED PROJECTS

None

REFERENCES

Au, W. W. L., Giorli, G., Chen, J., Copeland, A., Jarvis, S., Morrissey, R., Moretti, D., and Klinck, H. (2013). "Nighttime Foraging by Deep Diving Echolocating Odontocetes off the Hawaiian Islands of Kauai and Ni'iahu as Determined by Passive Acoustic Monitors," J. Acoust. Soc. Am. 133, 3119-3127.

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.