Beaked whales use alternating echolocation regimes during the descent phase of deep foraging dives

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METHODOLOGY

- Bottom-mounted High-frequency Acoustic Recording Packages (HARPs) were deployed at a variety of sites in the Gulf of Mexico (GofMX), Southern California Bight (SOCAL), and Pacific Islands region.
- Beaked whale (BW) echolocation signals in the data sets were automatically detected and classified to species level using MATLAB-based custom routines.
- Echolocation behavior was further scrutinized by examining patterns in inter-click interval (ICI) over the course of the acoustic encounters. In encounters where a BW was found to modify its clicking rate during the descent phase of the foraging dive (see Gassmann et al. 2015), the rate at which the whale decreased its ICI over time was measured using linear regression analysis (Figure 1).

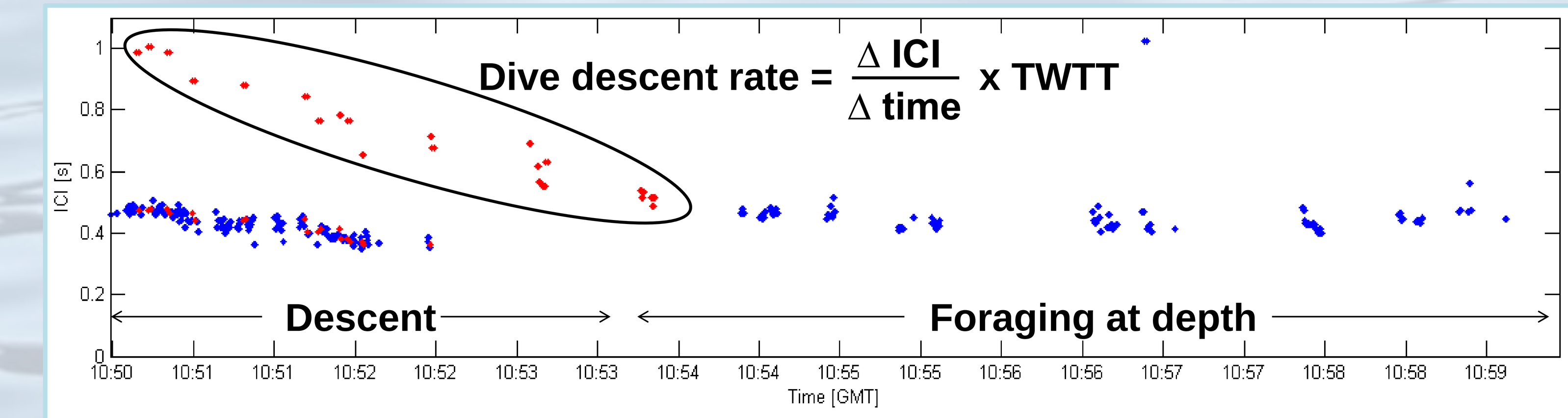

Figure 1. An analyzed acoustic encounter of a Cuvier's BW in which the rate of change within the 'long ICI' regime was calculated using linear regression analysis. By using a TWTT multiplier of 750 m/s, this measurement was then converted into an estimate of dive descent rate.

- When a BW alternated between two echolocation inspection ranges, the timing of the 'long ICI' regime was assumed to correspond to the delay necessary to wait for a seafloor echo to return, and the rate at which this target range changed over time served as a proxy for the whale's decreasing distance to the seafloor. Thus, given that the speed of sound in seawater is ~1500 m/s, a two-way travel time (TWTT) multiplier of 750 m/s was used to convert the measured rate of change within the 'long ICI' (seafloor-tracking) regime into an estimate of dive descent rate.

RESULTS

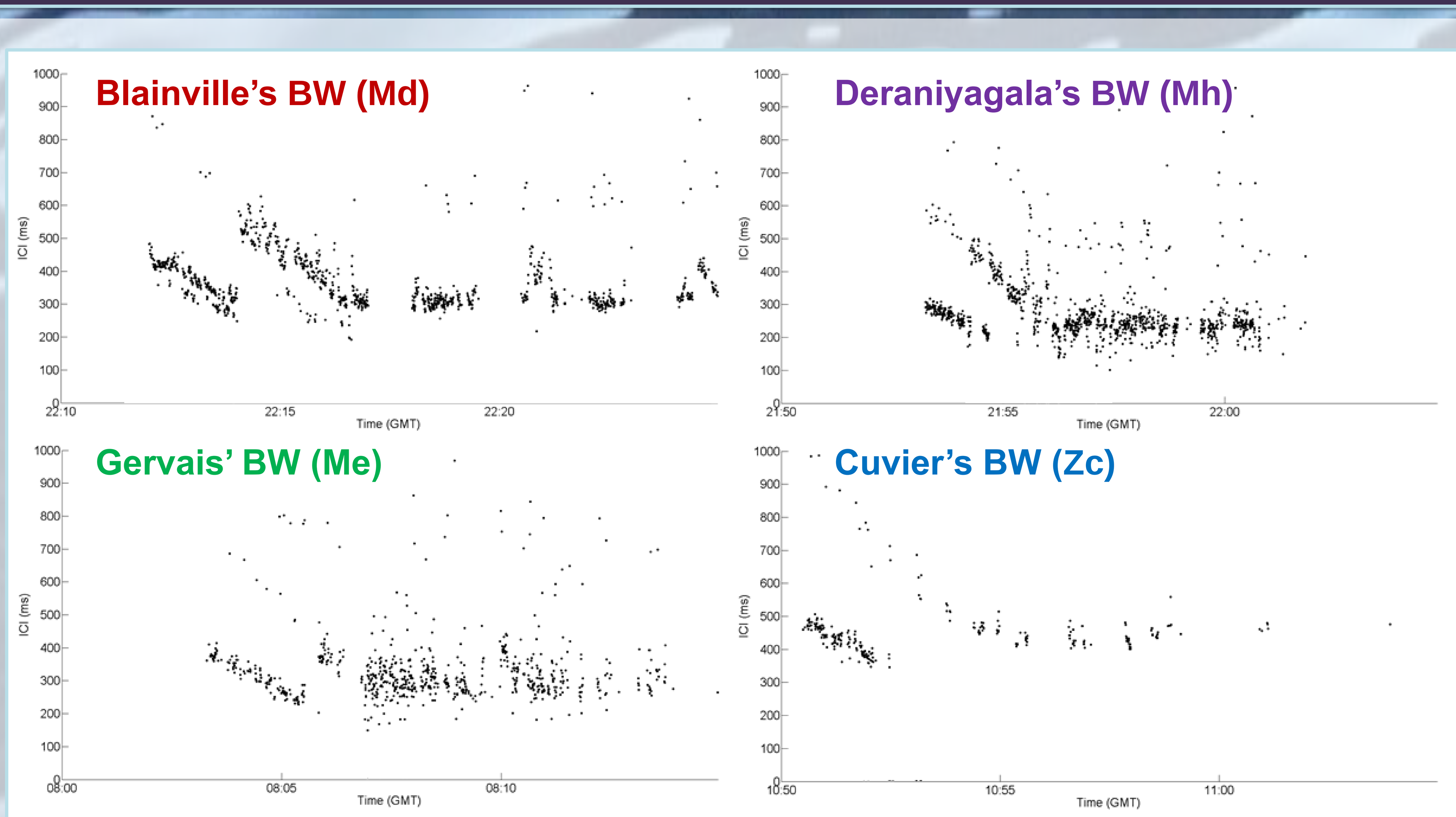

Figure 2. Example acoustic encounters showing ICI (black dots) as a function of dive time. In each encounter, the recorded animal gradually reduced the time interval between successive clicks while also alternating between two ICI regimes. Once the whales reached the bottom phase of their dive and began actively foraging at depth, they switched to a single, stable ICI regime.

- This echolocation behavior was documented in several acoustic encounters of Blainville's (*Mesoplodon densirostris*), Deraniyagala's (*M. hotaula*), Gervais' (*M. europaeus*), and Cuvier's (*Ziphius cavirostris*) BWs (Figure 2).
- The dive descent rate estimates (Figure 3) generally fell between 1-2 m/s, which is in broad agreement with published values obtained with animal-attached tags.

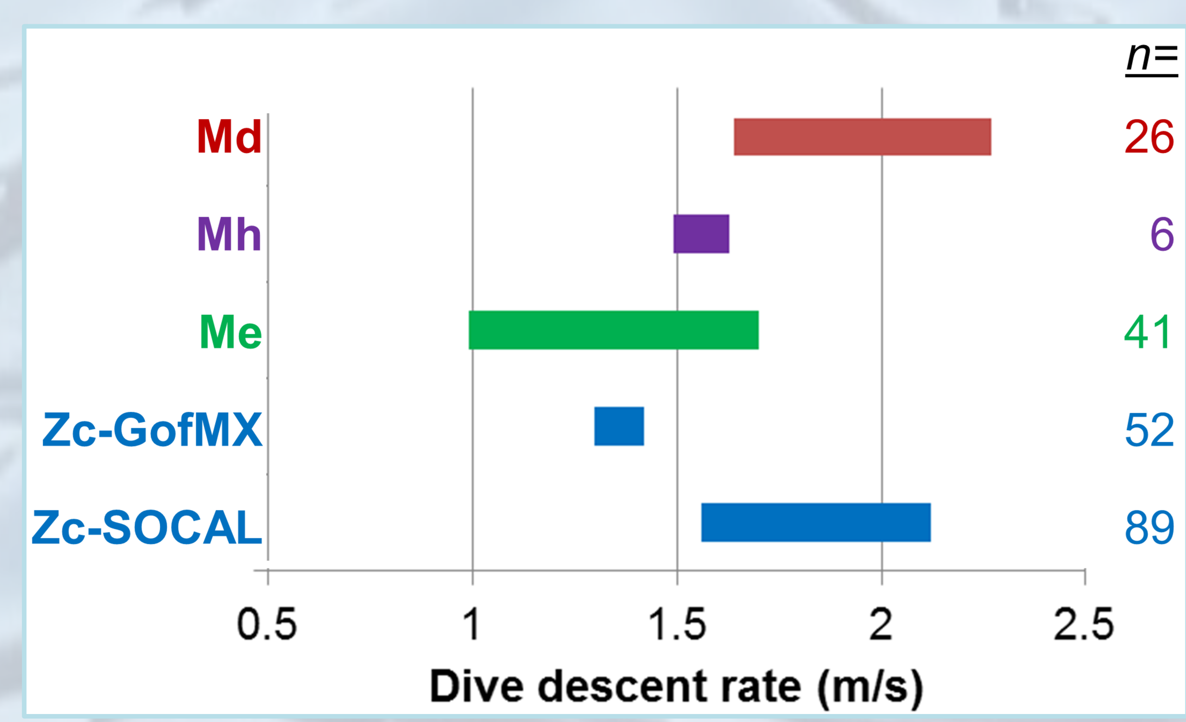

Figure 3. Range of mean dive descent rates over all sites per species (*n* is the number of measurements).

DISCUSSION

- Long-term acoustic recordings collected with autonomous instruments can provide insight into the ecology and behavior of rarely observed cetaceans, and these data suggest that BW echolocation behavior is not stereotyped over the course of deep foraging dives.
- This variability in click production rate at the start of foraging dives presumably represents a "multi-tasking" strategy, by which BWs are able to simultaneously monitor two different target ranges as they vertically approach their preferred foraging depths. The 'long ICI' regime potentially corresponds to the two-way travel time of sound to the seafloor, and thereby serves to track the ocean bottom. The 'short ICI' regime is consistently more rapid, and represents a shorter search range that is presumably used by the whales to inspect the nearby water column for prey and other features.
- Other deep-diving cetaceans, including sperm whales, pilot whales, and Risso's dolphins, have been found to track a target at depth during their dive descents, but the use of a second echolocation regime to concurrently inspect nearby surroundings so far appears to be unique to beaked whales.
- Passive acoustic monitoring has proven useful to investigate BWs, as they are generally difficult to study with visual survey techniques. However, these findings hold implications for density estimation methods, as a vocal cue rate multiplier is necessary for estimates of animal density based on passive acoustic data.

Reference and Acknowledgments

Gassmann, M., Wiggins, S. M., and Hildebrand, J. A. (2015). "Three-dimensional tracking of Cuvier's beaked whales' echolocation sounds using nested hydrophone arrays," J. Acoust. Soc. Am. 138, 2483-2494.

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