Bryde's whale behavioral metrics in the Southern California Bight from acoustic array tracking

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Objective

Provide the quantitative foundation required for sound impact studies as well as a population density estimate of Bryde's whales (*Balaenoptera edeni*) in the Southern California Bight (SCB) by developing behavioral metrics for the following biologically important behaviors:

- swimming speeds
- calling rates
- source levels

Southern California Bight

Figure 1. Location of the seafloor array (yellow star) in the Southern California Bight.

- highly productive ecosystem
- attracts a variety of cetaceans
- area of high anthropogenic activity
- ocean noise dominated by low-frequency (< 100 Hz) sound from commercial shipping as well as high frequency (> 1 kHz) sounds from sonar activity

Bryde's Whale Be4 Call

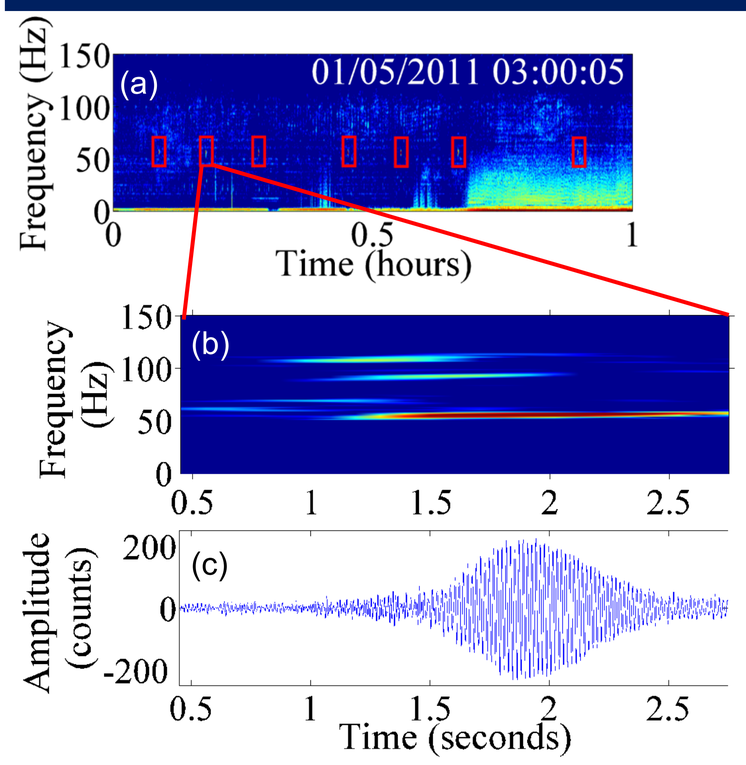


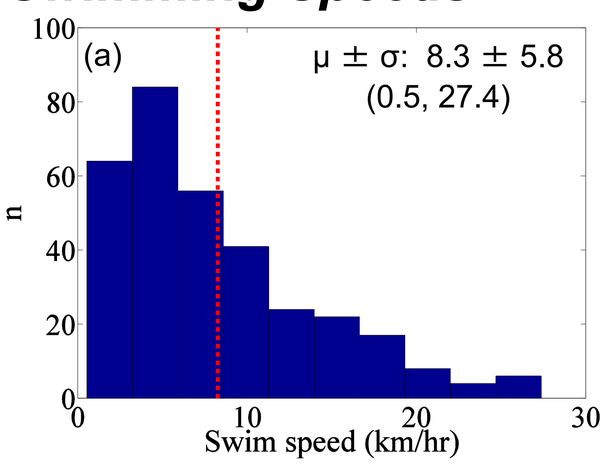
Figure 2. Bryde's whale Be4 call
(a) long-term spectral average (LTSA) with calls highlighted with red boxes,
(b) spectrogram parameters: Hanning window, Fs = 2000 Hz, NFFT = 2000, overlap = 90%; band pass filter = 55-150 Hz, and
(c) time series.

Color for both (a) and (b) represents spectrum level, with red as the highest intensity.

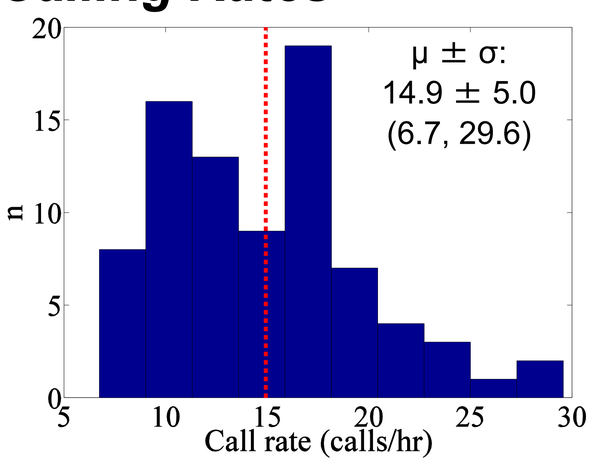
- most energy at 57 Hz
- possibly a social call; often emitted in presence of two or more animals
- recorded from southwest coast of Baja California to SCB
- rare call in SCB used as indicator of Bryde's whale acoustic presence

Results

Swimming Speeds



Calling Rates



Source Levels

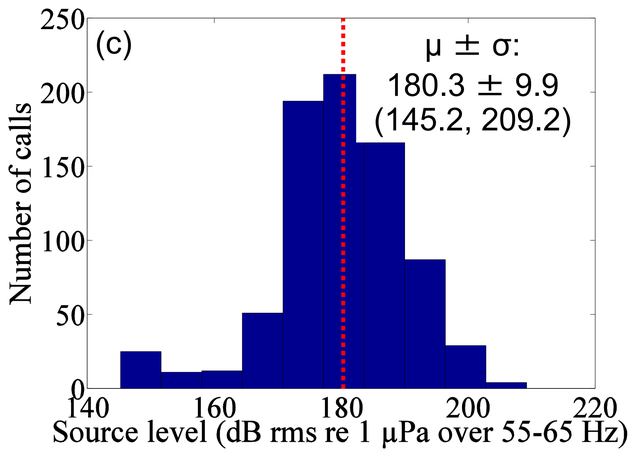
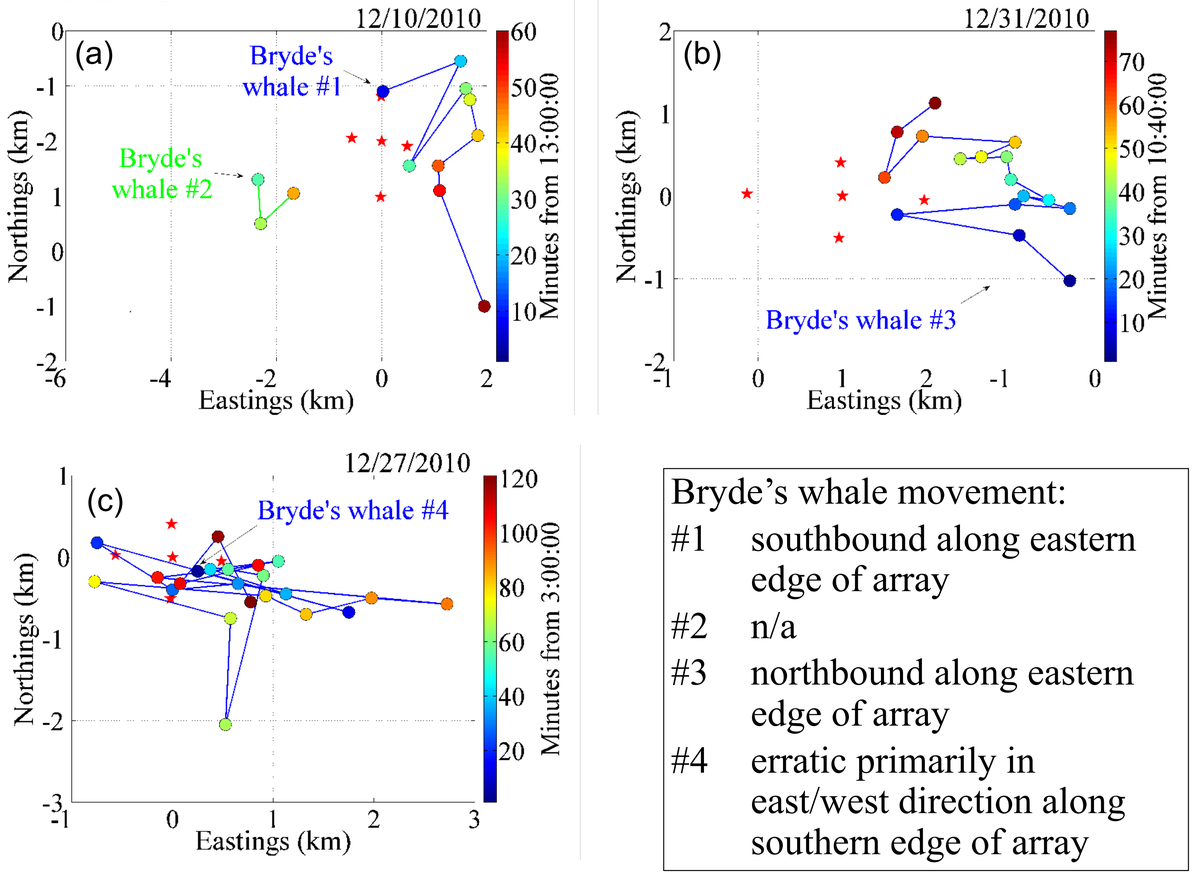


Figure 3. Histograms of:
(a) swim speeds (n = 326),
(b) call rates (n = 82), and
(c) source levels (n = 781) of calls recorded at HARP C.

Dashed red line marks average (μ). Range included in parentheses.

Tracks



Bryde's whale movement:

#1	southbound along eastern edge of array
#2	n/a
#3	northbound along eastern edge of array
#4	erratic primarily in east/west direction along southern edge of array

Figure 4. Tracks of four Bryde's whales in the SCB during December 2010.

Table 1. Average ± one standard deviation of call rate, swim speed and source level for each Bryde's whale track shown in Figure 4.

Bryde's Whale no.	Call Rate (calls/hr)	Swim Speed (km/hr)	Source Level (dB rms re 1 μPa over 55-65 Hz)
#1	10.3	8.5 ± 6.4	187.1 ± 9.3
#2	12.3	4.6 ± 0.7	182.9 ± 5.5
#3	15.0	5.3 ± 2.8	186.4 ± 5.8
#4	11.9	13.5 ± 6.9	173.6 ± 7.6

Methods

Sampling

- large-aperture (~1 km spacing) seafloor array of five High-frequency Acoustic Recording Packages (HARPs) (Fig. 5)
- deployed from December 2010 to February 2011

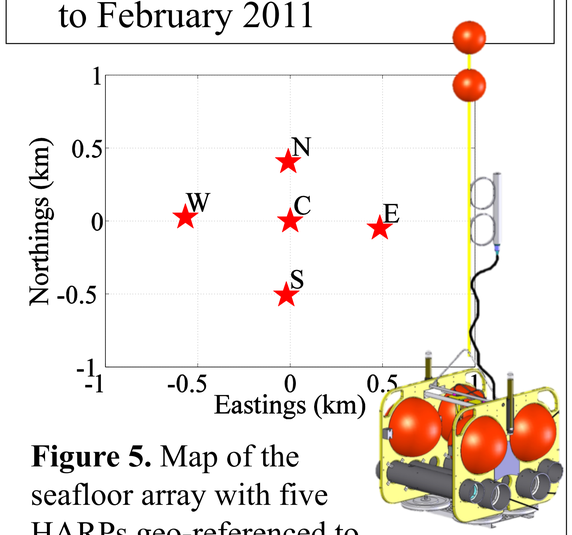


Figure 5. Map of the seafloor array with five HARPs geo-referenced to HARP C (32° 22.194 N, 118° 33.774 W).

Data Processing Steps

1. determined HARP locations using two-way travel times of pings to GPS-located ship (Fig. 5)
2. calculated modeled time-difference-of-arrivals (TDOAs) for each grid point (10 km x 10 km search box with 25-m grid spacing) using a homogeneous sound speed
3. manually detected Bryde's whale Be4 calls (Fig. 2)
4. applied 55-65 Hz band pass filter
5. computed TDOAs of each call by cross-correlating waveforms
6. applied least-squares minimization between measured and modeled TDOAs to determine location of each whale call
7. calculated swimming speeds, calling rates and sound source levels

Conclusions

- Bryde's whale movements can be regular with clear direction or erratic
- swimming speeds vary greatly, even within a single track, but are generally within currently published ranges (2-25 km/hr)
- calling rate is reasonably constant
- source level higher than other Bryde's whale calls (e.g., Be9 call $SL_{peak\text{-}to\text{-}peak}$ = 155 ± 14 dB re 1 μPa @ 1 m), but similar to other baleen whales

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