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Fish vertical distribution and marine mammal co-occurrence off Cape Hatteras, NC

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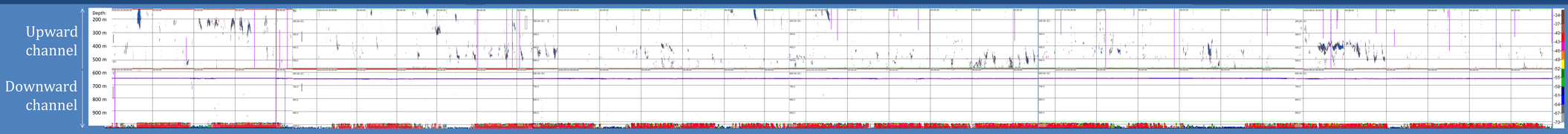

Echogram with -70 dB threshold. Data spans from March 9-August 31, 2016. Echograms from both transducers (one facing upwards, one facing downwards) are displayed. A resample variable was used to generate mean value of every 20 pings.

Introduction:

Mesopelagic (mid-water) fish are important components of toothed whale (Odontocete) diets. Few studies have simultaneous measurements of predator occurrence and potential prey density distributions over long durations. Echoshounder and hydrophone measurements were used to characterize vertical distributions of potential prey and relative abundance of 7 marine mammal groups in the water column off Cape Hatteras, NC. Co-occurrence of the two groups was used as an index of predator-prey interaction.

Objective:

Characterize potential predator-prey interactions by comparing passive and active acoustic data.

Methods:

Passive acoustic data

Data was collected from a HARP (High-frequency Acoustic Recording Package) (Fig. 1). Counts of vocalization occurrences were supplied by Dr. Doug Nowacek, Duke University. Counts were separated into species groups and binned in 4 tidal categories using NOAA's TEC2789 tide station.

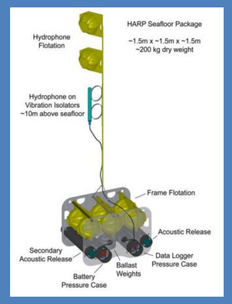

Fig. 1. Diagram of the HARP (source: Wiggins and Hildebrand, Scripps Institution of Oceanography).

Fig. 2A. Upward facing transducer mounted on the top of the mooring sphere.

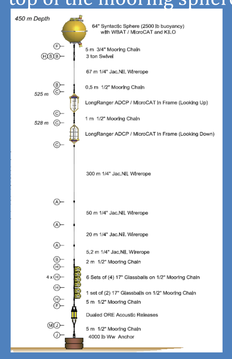

Fig. 2B. The Duke Wizard deployed off Cape Hatteras.

Active acoustic data

Data was collected using a 70 kHz WBAT echosounder on the Duke mooring (Fig. 2a,b). Upward and downward looking channels were calibrated using a calibration sphere and theoretical measurements. Data quality control and export was completed in Echoview. Fish density distribution data was characterized using four metrics (Table 1).

Table 1. Four metrics used to characterize vertical distribution of fish.

Quantity	Metric	Formula
Density	Mean volume-backscattering strength	$10 \times log_{10}(\frac{\int s_v(z)dz}{H})$
Location	Center of mass	$\frac{\int z\, s_v(z)dz}{\int s_v\,(z)dz}$
Dispersion	Inertia	$\frac{\int (CM-z)^2 s_v(z)dz}{\int s_v(z)dz}$
Patchiness	Aggregation index	$\frac{\int s_v(z)^2 dz}{(\int s_v(z)\,dz\,)^2}$

Data Synthesis:

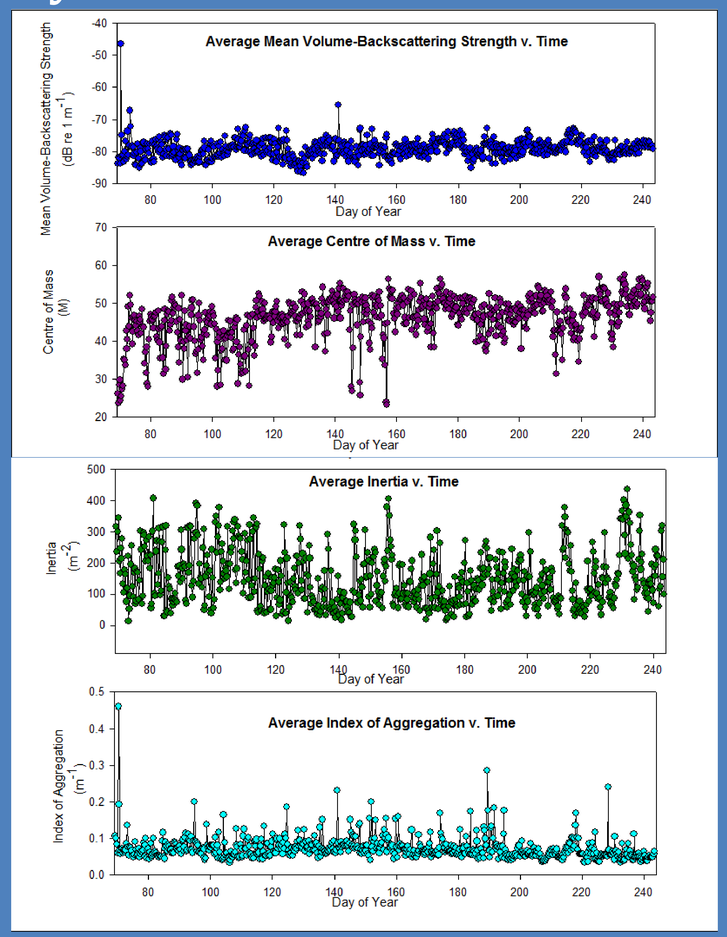

Figure 3. Four metrics plotted as 6-hourly averages visualized as a function of Julian day.

Analysis:

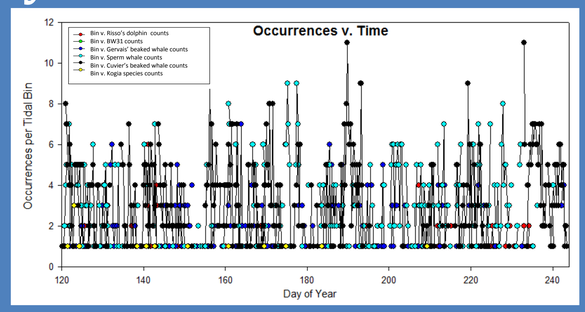

Figure 4. Number of Odontocete vocalization occurrences per approximately 6-hour tidal bin visualized as a function of Julian day.

Table 2. Correlation matrix of fish densities and marine mammal occurrences with fish density distribution metrics and environmental variables at daily resolutions.

	Sv (-70 dB)	COM(-70 dB)	Inertia (-70 dB)	IA (-70 dB)	Salinity	Temperature
Sv (-90dB)	0.869 (1.951E-039)	0.0284 (0.754)	-0.191 (0.0326)	-0.0335 (0.710)	-0.0235 (0.795)	-0.0567 (0.530)
Kogia species	0.0882 (0.328)	0.132 (0.142)	-0.189 (0.0346)	0.156 (0.0828)	-0.0223 (0.805)	0.00496 (0.956)
Cuvier's beaked whale	0.219 (0.0142)	0.00968 (0.915)	-0.162 (0.0714)	0.0944 (0.295)	0.0157 (0.862)	0.0274 (0.762)
Sperm whale	0.0771 (0.393)	-0.0990 (0.272)	0.0448 (0.620)	0.280 (0.00158)	0.242 (0.00665)	0.306 (0.000526)
Gervais' beaked whale	0.106 (0.259)	0.00545 (0.952)	-0.0600 (0.597)	-0.0380 (0.674)	-0.171 (0.0560)	-0.205 (0.0200)
Risso's dolphin	-0.143 (0.112)	-0.206 (0.0210)	0.0834 (0.554)	0.0829 (0.558)	0.0898 (0.508)	0.0857 (0.342)
BW31	0.188 (0.0362)	0.0656 (0.538)	0.0267 (0.767)	0.109 (0.227)	0.184 (0.0396)	0.105 (0.242)
Unidentified Odontocete	0.150 (0.0949)	0.0463 (0.609)	-0.0249 (0.783)	-0.0148 (0.870)	-0.149 (0.0983)	-0.129 (0.151)

Table 3. Correlation matrix of fish densities and marine mammal occurrences with fish density distribution metrics and environmental variables at 6-hr resolutions.

	Sv (-70dB)	CM (-70dB)	I (-70dB)	IA (-70dB)	Salinity	Temperature
Sv (-90dB)	0.883 (1.679E-164)	-0.107 (0.0178)	-0.223 (0.000000528)	0.154 (0.000564)	-0.0227 (0.414)	-0.0432 (0.336)
Kogia Species	0.465 (0.110)	-0.296 (0.327)	-0.0572 (0.853)	-0.151 (0.622)	0.135 (0.661)	0.125 (0.685)
Cuvier's beaked whale	-0.0284 (0.640)	-0.0897 (0.138)	0.168 (0.00532)	0.0305 (0.616)	0.114 (0.0599)	0.126 (0.0378)
Sperm whale	0.0955 (0.156)	-0.00255 (0.972)	-0.0838 (0.191)	-0.0253 (0.693)	-0.197 (0.00192)	-0.191 (0.00268)
Gervais' beaked whale	0.0352 (0.678)	0.0371 (0.620)	-0.0747 (0.318)	-0.0152 (0.839)	0.208 (0.00486)	0.189 (0.0108)
Risso's dolphin	0.139 (0.259)	0.0601 (0.628)	-0.122 (0.322)	0.247 (0.0422)	0.287 (0.0177)	0.290 (0.0166)
BW31	0.000 (--)	0.000 (--)	0.000 (--)	0.000 (--)	0.000 (--)	0.000 (--)
Unidentified Odontocete	0.186 (0.0387)	-0.0223 (0.806)	-0.0237 (0.794)	0.0137 (0.880)	-0.0498 (0.653)	-0.00267 (0.977)

Yellow: p<0.05

Orange: p<0.005

Red: p<0.0005

Discussion:

- The fish and zooplankton density index S_V (-90 dB) was significantly correlated with the fish density index S_V (-70dB). Fish distribution indices CM (-70dB), I (-70dB), IA (-70dB) were correlated with the fish and zooplankton density index S_V (-90dB) at the 6-hour resolution.
- There were fewer than expected (2/7 daily resolution; 1/7 6-hourly resolution) significant correlations between the number of marine mammal occurrences and the potential prey field density. There were no significant distributional correlations when there were significant density correlations.
- At both resolutions, Cuvier's and Gervais' beaked whales and Sperm whales were correlated with salinity and/or water temperature.
-Further research is necessary to determine whether metrics of preyfield density influence the occurrence and potential foraging of Odontocete marine mammals.

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