Supporting Information: Shipboard Acoustic Observations of Flow Rate from a Seafloor Sourced Oil Spill

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1 ADCP Horizontal Current Calculation

The ADCP was oriented so that beam 3 (the "forward" beam in beam coordinates) was oriented 45° to port of the forward direction of the vessel. Each beam of the ADCP is oriented 20° from nadir. Raw beam coordinate data was first transformed to ships coordinates to obtain the forward (V_{fwd}), starboard (V_{stbd}) and vertical velocities (V_v) according to;

$$V_{stbd} = \frac{1}{2}\left[\frac{b_3 - b_4}{sin(20)}\right]sin(45) + \frac{1}{2}\left[\frac{b_1 - b_2}{sin(20)}\right]cos(45), \tag{1}$$

$$V_{fwd} = \frac{1}{2}\left[\frac{b_4 - b_3}{sin(20)}\right]cos(45) + \frac{1}{2}\left[\frac{b_1 - b_2}{sin(20)}\right]sin(45), \tag{2}$$

$$V_v = \frac{b_1 + b_2 + b_3 + b_4}{4\,sin(20)}, \tag{3}$$

where b_1, b_2, b_3 and b_4 are the along beam velocities of beams 1, 2, 3 and 4 respectively. The velocity measurement at the seafloor was then subtracted from the recorded velocities to account for the movement of the vessel. Finally, the ships coordinate data

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was transformed to earth coordinates using the heading recorded by the ADCP, plus an offset of 45° to account for the orientation of beam 3. The error velocity and percent good were also calculated. The error velocity is a measure of the heterogeneity of the vertical velocity measurements. ADCP measurements assume that the flow is homogeneous within a sample and a high error velocity indicates that the flow at a given depth is heterogeneous resulting in errors in estimates of the horizontal velocity. The percent good is a measure of the percent of pings that pass a correlation threshold, set to the manufacturers suggested value of 120 (correlation is a unit-less value determined by the correlation performed by the instrument). Any pings with an error velocity above 0.3 m/s were rejected. Pings were then ensembled into 20 ping ensembles at each depth. Any depth measurements with ensembles that had fewer than 30% of measurements pass the correlation threshold and error velocity threshold were rejected.

2 Seep Origin

Nine along-seep echo sounder survey lines were used to determined the seep origin. TS was averaged over five meter depth bins for all pings in the area immediately above the downed jacket (108 - 113 m depth; Figure 5). The very strong backscatter from the downed jacket masks any signal from the seep at greater depths, and determination of the origin was limited to depths above the jacket. A three dimension local linear interpolation was fit to the depth averaged TS as a function of position (Fig. S1). The interpolation revealed the presence of two main peaks, indicating the presence of two sources sources in agreement with Mason et al (2019) referenced in the main text. Peak contours of the interpolation were defined as points within 3dB of the maximum TS. The center of mass of each of the two contours was found to determine the “origin” of each seep. At a range of 110.25 meters, the beam has a diameter of 10 meters, and the location of the peaks of the interpolation have a maximum accuracy of 10 meters. The northern seep is located at 28.93728 N x -88.96948 W ±10 m and the southern seep at 28.93714 N x -88.96950 W ±10 m. The seep origin is an estimate of the position of the seeps at the center of the depth bin (110.25 m), and not an estimate of the position of the seeps on the seafloor.

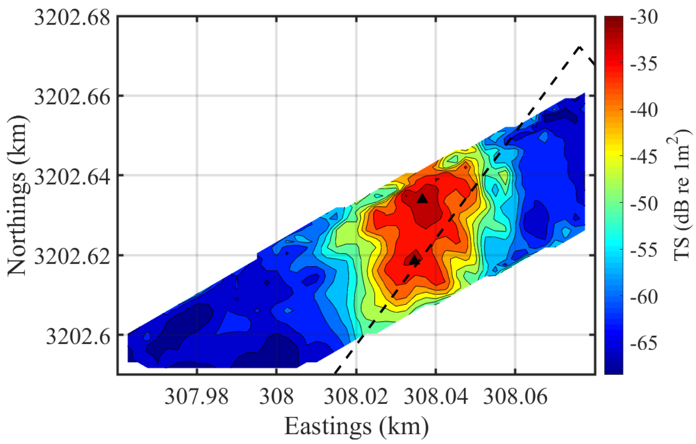

Figure S1: Linear interpolation of the TS averaged over 108 - 113 m depth for the area surrounding the downed jacket. The black triangles indicate origins of the two seeps. The origins are the areas of maximum backscatter at depths immediately above the downed jacket. The jacket itself masked the return from the seep at depths below 113 m. Contour lines are equal a change of 3 dB.

3 Split-beam Beam Angle Information

3.1 Discretely Scattering Seep

Volume scatterers are scatterers of sound that collectively are larger than the ensonified volume of the echo sounder and therefore the targets fill the entire volume. Deep scattering layers, for example, are treated as volume scatterers because the layer is much larger than the ensonified volume. For such targets, the target strength is divided by the ensonified volume to determine the scattering per unit volume. An individual target, such as a single fish or bubble, is treated as a single scatterer. Beam angle data from the split-beam echo sounder used in this experiment indicated that the seep was narrower than the width of the acoustic beam, and that the scattering from the target was constrained to a fraction of the beam. This conclusion lead to the treatment of the seep in this study as a discrete target composed of bubbles and droplets.

The beam angle data from the split beam echo sounder can be used to determine if a target is a discrete or volume scatterer. The beam angle is determined by the relative phase of the sound incident on the quadrants of a split-beam echo sounder. As the echo sounder approaches the target, the target will move from a large magnitude angle

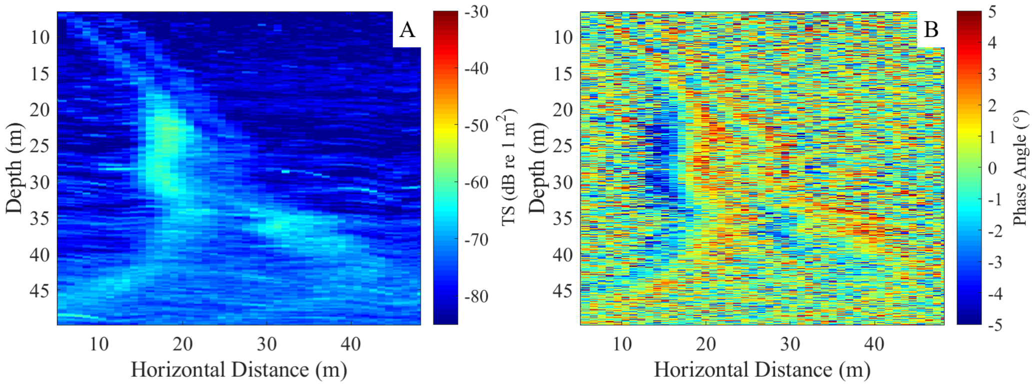

Figure S2: (A) A zoomed in version of the echogram in Figure 5F focused on the seeps. (B) The phase angle for the seeps as the vessel crosses over them. The angle goes from negative to positive as the seep transitions across the beam, and then the transition from negative to positive repeats for the second seep. Combined with the seep origin analysis, this indicates the presence of two distinct seeps in the water column that do not fill the ensonified volume.

(positive or negative magnitude depending on orientation of the echo sounder) to a minimum angle - the MRA if the target passes directly below the echo sounder - and then back again to a large magnitude angle as the echo sounder moves away from the target. If a randomly distributed target completely fills the volume ensonified by the beam, the relative phase will appear incoherent and randomly distributed.

The phase angle for the seep in this study follows the pattern of a discrete target (Figure S2). The seep can be thought of as a narrow vertical column of bubbles and droplets that was narrower than the width of the acoustic beam. The scattering was modeled where the seep is a discrete target comprised of bubbles and droplets that in a column narrower than the acoustic beam.

3.2 Split Seep in the Water Column

The beam angle data also shows the presence of two seeps in the water column. The beam angle goes from large magnitude beam angle to small angle and then back to large angle as the echo sounder moves over the target. This occurs twice for across-seep passes as the echo sounder moves over the first seep and then the ramp in beam angle occurs again for the second seep (Figure S2).