CRUISE RESULTS
NOAA Fisheries Research Vessel Henry B. Bigelow
Cruise No. HB 10-06
Sub-surface Oil and Ecological Impacts (Gulf of Mexico)

PREPARED BY:
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CRUISE PERIOD AND AREA

18 July – 28 August 2010

The vessel departed Newport, Rhode Island on 18 July and transited to Key West, Florida. Most scientist and supplies staged in Key West and the vessel departed for the Deepwater Horizon Incident site on 28 July. The vessel worked primarily within 10 km of the Deepwater Horizon wellhead for Leg 1. The vessel put in to Pascagoula, Mississippi on 10 August at the end of the first leg and exchanged scientists, offloaded samples and took on some additional supplies. The vessel sailed on 13 August for the start of Leg 2. Work was preformed in the vicinity of the wellhead but also up to 60 km from the wellhead. The vessel returned to Key West on 22 August and offloaded scientists and then proceeded to Newport, Rhode Island arriving 28 August. See Figure 1for the large-scale area of operation.

OBJECTIVES:

1) Conduct acoustic surveys in the vicinity of the Macondo well and the Deepwater Horizon MC252 site with the EK60 to contribute to NOAA's ongoing wellhead monitoring efforts.
2) Conduct acoustic surveys in the area surrounding the Deepwater Horizon MC252 site with the EK60 to provide more information regarding the release of oil and gas from the bottom.
3) Perform conductivity temperature depth (CTD) profiles to map the deepwater hydrocarbon plume and to provide near-real time guidance in the collection of water samples to study the plume.
4) Collect water from beneath, within, and above a high fluorescence-low dissolved oxygen layer at about 800-1200 m for polycyclic aromatic hydrocarbons (PAH), volatile organic compounds (VOC) and dissolved oxygen.
5) Make direct dissolved oxygen measures using the Winkler method to calibrate the CTD-based dissolved oxygen sensor.
6) Measure Volatile Organic Compounds from select water samples onboard ship using a portable gas chromatograph.

METHODS:

Acoustics (Objectives 1 and 2) - Acoustics (Objectives 1 and 2) - Acoustic data were collected with the EK60 at 18 and 38 kHz. The 70, 120, and 200 kHz were not used because of possible interference with efforts to monitor, cap, and seal the wellhead. In the vicinity of the well, transects were made over the wellhead. The direction, length, and number of transects performed was largely determined by position and movement of other ships working in the wellhead area. Outside of the wellhead area, acoustic operations were conducted to cover as much of the surrounding area as possible. Echograms of raw sonar data were produced onboard in real time using EchoView® software. "Features" that appeared to be 'natural' seeps were marked and often revisited. Acoustic data were relayed hourly to a Subsurface Monitoring Unit ftp site for analysis onshore.

CTD Casts (Objectives 3) – CTD casts were performed with a SeaBird 911 CTD. Additional sensors included an altimeter, a dissolved oxygen sensor (SBE 43), and a Colored Dissolved Organic Matter Fluorometer (Wet Labs ECO-CD(RT)). Casts were preformed to within 50 m of the bottom or to a maximum depth allowed by the amount of wire on the drum. CTD data were recorded in real time on a shipboard computer. Data were uploaded to a Subsurface Monitoring Unit ftp site nightly.

Water samples (Objective 4) – Water samples were taken below, in, and above the zone previously identified as the area of the sub-surface plume. Water samples were collected with Teflon-lined 5L niskin bottles supplied by OceanTest Equipment. The Natural Resource Damage Assessment protocols were followed (see Appendix 1). Supplies were obtained from the NRDA contractor Dade Moeller and Associates. No surface oil was encountered so provisions referring to surface oil in the protocols were not applicable. Waters samples were preserved following the NRDA protocol and transferred to NRDA staff within 5 days of collection.

Dissolved oxygen measurements (Objective 5) – Previous cruises in the Deepwater Horizon Incident Site area found decreases in dissolved oxygen at depth suggesting increased microbial degradation of hydrocarbons. However, the accuracy of dissolved oxygen measurements from membrane-based sensors was questioned by the Joint Analysis Group necessitating calibration using Winkler Titrations. An automated-titrator designed by Chris Langdon (RSMAS) was provided by AOML and one member of the scientific party was trained in its operation. Water samples were taken from the rosette first for dissolved oxygen analysis so as to insure minimal atmospheric exposure.

Measure Volatile Organic Compounds (Objective 6) – A portable gas chromatograph (GC) was used to measure Volatile Organic Compounds from a subset of water samples collected with the CTD. The GC was a ***Smart Plus 008*** and the analyst was contracted from KD Analytical (www.kdanalytical.com).

RESULTS:

Acoustics (Objective 1 and 2) – Acoustic data were collected over nearly 3000 miles of the Bigelow's trackline. Most of the effort was in the vicinity of the wellhead

(Objective 1) but some effort was in the areas surrounding the wellhead (Figure 2). The wellhead acoustic monitoring consisted of making transects over and in the vicinity of the Macondo well. Data were collected prior to and following the static kill procedure. Prior to the static kill operation, a clear strongly reflective vertical feature was present in the lower half of the water column in the vicinity of the wellhead with little indication of false returns from beneath seabed (Figure 3). This feature was interpreted as a physical plume of gas bubbles rising through the water column. This feature resembles acoustic patterns observed over locations of known and suspected natural methane seeps. After the static kill operation, a vertical feature was still evident over the wellhead but weaker and with greatly increased false returns from below the seabed surface (Figure 3). This latter pattern suggested the presence of a substantial amount of noise in the water column over the wellhead following the static kill. The source of this noise is unclear. Preliminary efforts to remove the background noise from the acoustic data by Dr. Paul Walline indicated a decrease in the amount of acoustic return over the wellhead after the static kill operation (Figure 4). These analyses are preliminary and subject to change; there are better methods to correct the acoustic data and to conduct a more quantitative analysis of the data. Our preliminary analyses are reported only as an indication of what was done during the cruise to understand the changing conditions and to adapt sampling to these changing conditions. See Appendix 2 for the methods used to make the background noise correction.

Strong horizontal layers of acoustic returns in the upper water column both over the wellhead and away from it (Fig. 2) were attributable to Deep Scattering Layers (DSL), primarily caused by aggregations of organisms (zooplankton, pelagic fishes and squid) in the water column. These typically exhibited vertical migration patterns around dawn and dusk. Broad differences in the reflectance patterns of these horizontal layers before and after the static kill occurred both over the wellhead and remote from it, suggesting temporal changes in the abundance and composition of the DSL not immediately related to the presence of the wellhead. In addition, an “acoustic deficit” appeared consistently in the deepest layers of the DSL directly over the wellhead and nowhere else. We interpreted this phenomenon as the displacement of some DSL organisms resulting from anthropogenic disturbances of the wellhead water column.

In addition to mapping the wellhead, regions surrounding the wellhead were mapped and several areas of vertical acoustic returns were identified in the lower half of the water column. These areas were interpreted as ‘natural’ seeps. In at least one case, the acoustic returns coincided with a pipeline marked on the nautical chart (Figure 5) and this was reported to the U.S. Coast Guard. A catalogue including the GPS positions and echogram images of all these features collected by *Henry Bigelow* was provided to the Subsurface Monitoring Unit.

<u>CTD Casts (Objectives 3)</u> - 63 CTD Stations were occupied (Figure 6). The rosette on a few casts malfunctioned and separate files were created. All CTD locations are listed in Table 1. There was very little evidence for a subsurface plume at the stations occupied at the time of the CTD casts. Small decreases ($\leq$ 0.2 mg/L) in dissolved oxygen were observed at a handful of stations (Figure 7). No increases in Colored Dissolved Organic

Matter were observed, suggesting little or no hydrocarbons in the water (Figure 8). It should be noted however that the CDOM fluorometer is an imperfect instrument for detecting hydrocarbons. Temperature and salinity profiles appeared normal for the location and the time of year (Figure 9 & 10).

Water samples (Objective 4) – Water samples were collected at most CTD stations. 1L samples were preserved for PAH analysis and 40mL samples were preserved for VOC analysis. Samples were kept in a walk-in refrigerator until transfer to the NRDA. Approximately 500 samples were collected for Total Polycyclic Aromatic Hydrocarbon analysis and approximately 1000 samples were collected for Volatile Organics analysis. Samples will be analyzed shore side by the NRDA contract laboratory.

Dissolved oxygen measurements (Objective 5) – Approximately 30 samples were collected for Winkler Titrations. The auto-titrator was damaged during the cruise because it was connected to the wrong power source. However, the data collected indicated excellent agreement between the membrane-based dO2 sensor and the dO2 concentrations determined via Winkler Titrations (Figure 11). Samples were also preserved at sea for analysis on shore.

Measure Volatile Organic Compounds (Objective 6) – Samples were taken for on-board Gas Chromatograph analysis for VOC from 64 sites across the area and from depths ranging from 2 to 1803 m. Toluene was found at concentrations ranging from 1.4 to 9.7 µg/L from six stations: all but one were within 10 km of the wellhead, and all positive samples were taken at depths ranging from 2 to 35 m. No other hydrocarbons were detected. The source of the toluene was not identified definitively, but the fact that contamination with this single aromatic hydrocarbon occurred only in near-surface waters and primarily where surface vessel and drill rig activity was high suggest that surface ships and/or drill rigs were the most likely source(s). This analysis was not capable of detecting volatile substances with molecular weights less than 42 amu, e.g. methane and hydrogen sulfide. Methane was likely present in one sample obtained from a natural seep plume and hydrogen sulfide was detected by smell in one bottom sample.

NAVO Glider Retrieval (Assigned en route) – During the course of the cruise, NOAA SMU assigned *Henry Bigelow* the task of retrieving two Naval Oceanographic Office autonomous gliders (nos. 135 and 137) from an area approximately 50 nmi SW of the wellhead on the morning of August 19th. This was accomplished by tracking each one individually using GPS signals emailed directly from the gliders, spotting them visually on the sea surface, easing the ship alongside, and then gently hoisting each aboard by hand. Each glider was shut down, cleaned of adhering oil with mild detergent, packed for shipping, and later transferred to the supply vessel *Gulf Majesty* for shipment ashore. The entire sequence from tracking the first glider to securing the second one onboard required about 3 hours (Figure 12).

Press Visits (Assigned en route) – During the course of the cruise, press visits and interviews were conducted by ABC News, NBC News, Associated Press, The New York Times Magazine, and the Times Picayune.

Surface Oil Observations: Due to concern with surface oil that could interfere with rosette casts, the condition of the sea surface was noted several times per day on an *ad hoc* basis (Figure 13). Large rafts of *Sargassum* weed were observed throughout the cruise (Figure 13a); to the untrained eye these occasionally appeared as slicks of oil mousse. On August 14th blobs of pale orange material were observed floating in the vicinity of the wellhead (Figure 13b). This was indeed oily material likely released as a result of power washing of the lower portions of the relief well platforms earlier in the same day. This was the only substantial oil observed on the surface during the cruise.

On August 16th and 18th multiple patches of light oil sheen were observed on the surface in the vicinity of the wellhead (Figure 13c). The patches ranged from about 0.5-4 m wide and often were clustered together near the wellhead. We also observed what appeared to be gas and oil bubbling up to the surface, which would result in an oil sheen spreading onto the surface. In addition, in close proximity to the areas of the oil sheen, slicks of white particulate material were observed in patches approximately 3-10 m wide (Figure 13d). Samples of the substance were taken and microscopic examination revealed it to be deteriorating plant material, with small snails feeding upon it (Figure 13e).

DISPOSITION OF SAMPLES AND DATA

Acoustic data was transferred to the Subsurface Monitoring Unit hourly.

CTD data was transferred to the Subsurface Monitoring Unit daily. In addition, the data will be stored in NEFSC OCDBS database.

Water samples and water sample metadata were transferred to the NRDA within 3-5 days of sample collection. Water sample metadata was also transferred to the Subsurface Monitoring Unit daily.

Dissolved oxygen measurements derived from Winkler titrations were transferred to the Subsurface Monitoring Unit periodically during the cruise.

Gas chromatograph results were transferred to the Subsurface Monitoring Unit by the KD Analytic technician at the end of each leg.

SCIENTIFIC PERSONNEL

Leg 1

Name	Role	Email
Jon Hare	Chief Scientist	jon.hare@noaa.gov
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Leg 2

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* Henry Bigelow survey technicians

Table 1 Location of CTD casts/ water sample collection

Station	Latitude	Longitude
** Station ID: 002	28.702	-88.336
** Station ID: 002	28.695	-88.334
** Station ID: 003	28.722	-88.322
** Station ID: 004	28.697	-88.225
** Station ID: 005	28.720	-88.286
** Station ID: 006	28.818	-88.300
** Station ID: 007	28.851	-88.264
** Station ID: 008	28.849	-88.240
** Station ID: 009	28.723	-88.323
** Station ID: 010	28.708	-88.336
** Station ID: 011	28.706	-88.396
** Station ID: 012	28.771	-88.341
** Station ID: 013	28.780	-88.371
** Station ID: 014	28.767	-88.400
** Station ID: 015	28.736	-88.412
** Station ID: 016	28.704	-88.395
** Station ID: 017	28.696	-88.356
** Station ID: 018	28.737	-88.266
** Station ID: 19	28.674	-88.295
** Station ID: 020	28.778	-88.365
** Station ID: 021	28.758	-88.331
** Station ID: 022	28.701	-88.359
** Station ID: 023	28.704	-88.394
** Station ID: 024	28.746	-88.466
** Station ID: 025	28.677	-88.438
** Station ID: 026	28.650	-88.372
** Station ID: 027	28.671	-88.293
** Station ID: 028	28.738	-88.268
** Station ID: 28 part 2	28.734	-88.265
** Station ID: 028 part III	28.729	-88.266
** Station ID: 029	28.696	-88.225
** Station ID: 030	28.697	-88.225
** Station ID: 031	28.647	-88.366
** Station ID: 032	28.669	-88.293
** Station ID: 033	28.746	-88.463
** Station ID: 034	28.675	-88.439
** Station ID: 035	28.739	-88.412
** Station ID: 036	28.701	-88.400
** Station ID: 037	28.710	-88.328
** Station ID: 038	28.741	-88.323

Table 1 continued

Station	Latitude	Longitude
** Station ID: 039	28.739	-88.269
** Station ID: 040	28.989	-87.829
** Station ID: 041	29.047	-87.685
** Station ID: 042	28.887	-87.622
** Station ID: 043	28.916	-87.472
** Station ID: 044	28.700	-87.453
** Station ID: 045	28.712	-87.604
** Station ID: 046	28.556	-88.589
** Station ID: 047	28.463	-88.703
** Station ID: 048	28.540	-88.365
** Station ID: 049	28.608	-88.368
** Station ID: 050	28.711	-88.351
** Station ID: 051	28.673	-88.358
** Station ID: 052	28.691	-88.367
** Station ID: 053	28.670	-88.366
** Station ID: 054	28.797	-88.384
** Station ID: 055	28.836	-88.363
** Station ID: 056	28.711	-88.368
** Station ID: cb	28.095	-88.589
** Station ID: 058	27.929	-88.406
** Station ID: 059	27.865	-88.800
** Station ID: 060	27.793	-88.931
** Station ID: 061	27.493	-89.424
** Station ID: 062	27.564	-89.310
** Station ID: 063	28.250	-89.269
** Station ID: 064	28.315	-89.141

Figure 1. Map of the working area.

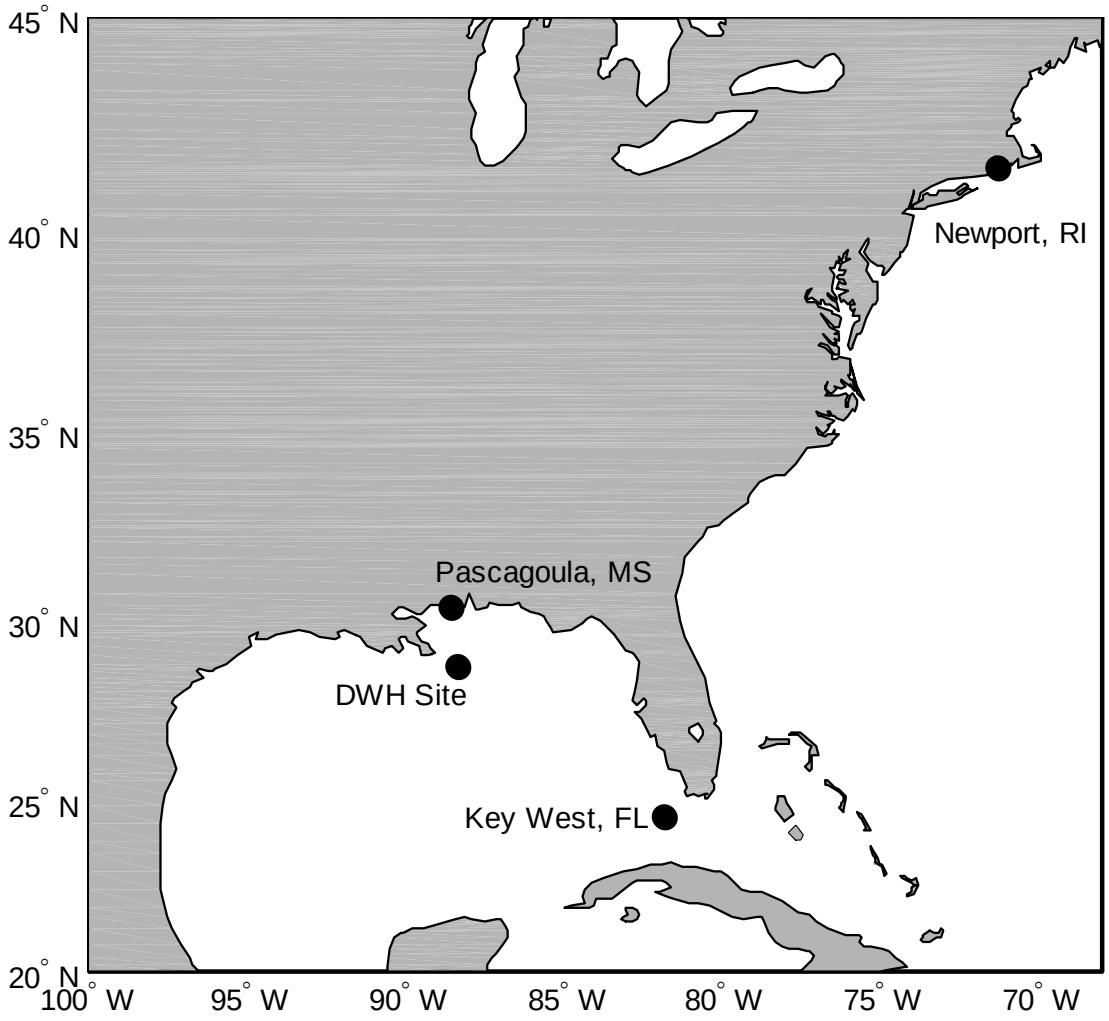


Figure 2. A) Map of Bigelow trackline indicating collection of acoustic data using the EK60. B) Highlight of trackline in the vicinity of the wellhead.

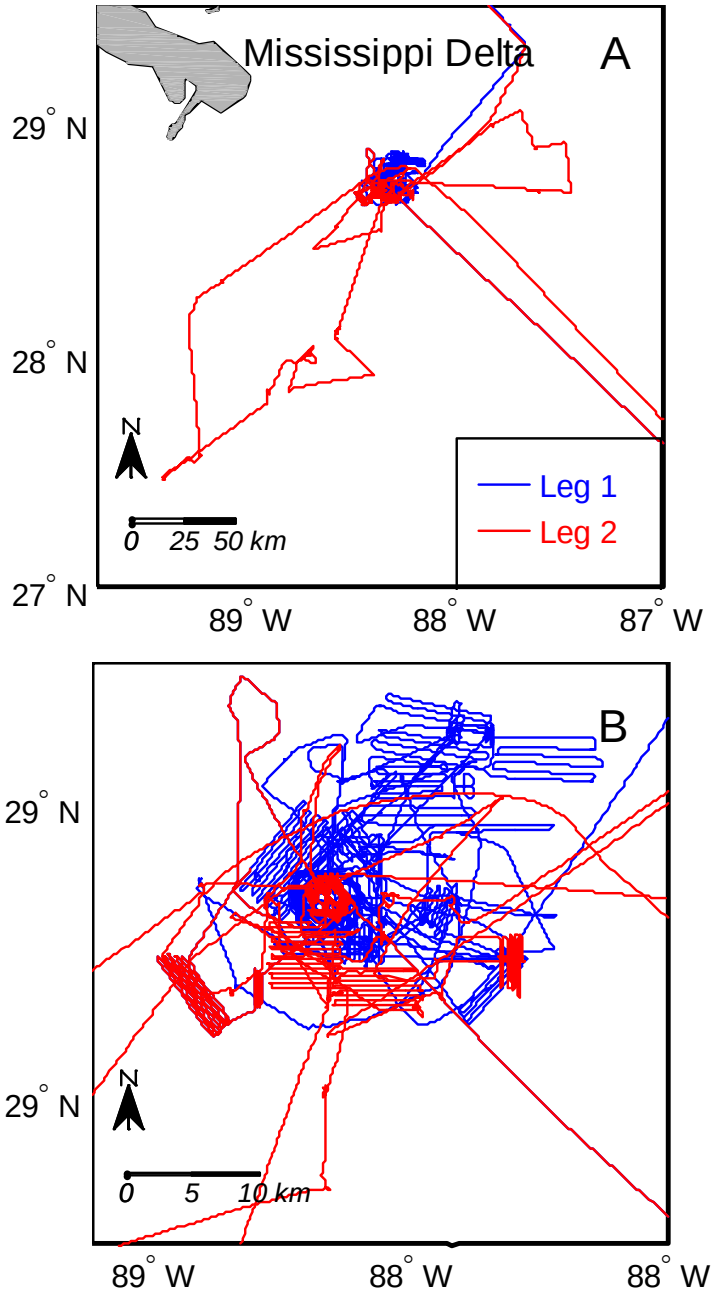


Figure 3. Echograms of 18 kHz EK60 data from before (pre) and after (post) the static kill operation. The multiple plumes represent multiple crossings over the wellhead.

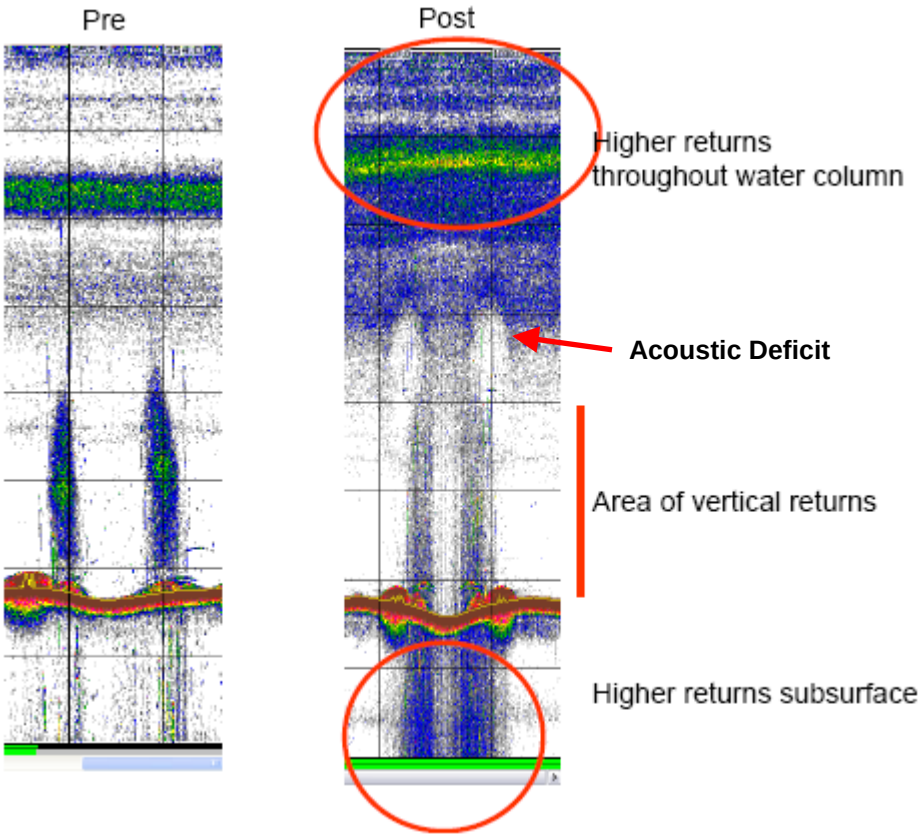


Figure 4. Preliminary analysis of the amount of acoustic return in the water column above the wellhead after removing background noise..

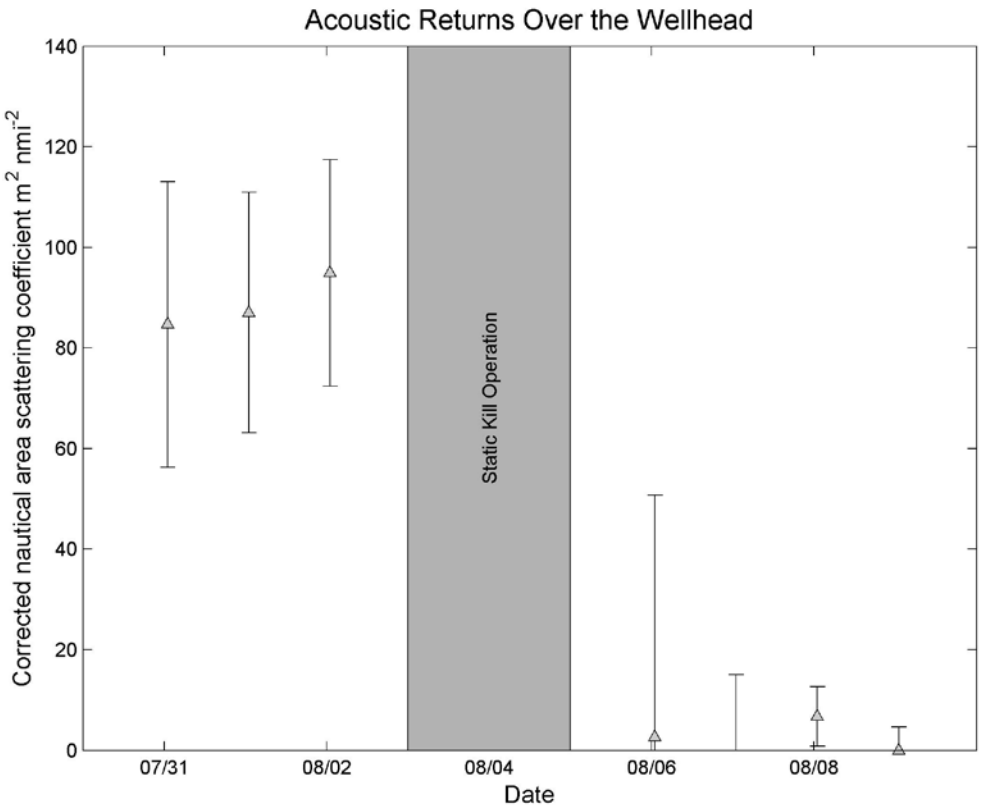


Figure 5. Area of high acoustic return associated with a pipeline to the west-southwest of the Deepwater Horizon incident site. Map shows location with respect to the DHW MC252 site (encircled in green) and surrounding mapping pattern lines (black). The heavy black circle shows the location of the pipeline-associated return. The 18 kHz echogram from that location is shown at the right. Red x's are similar sonar features. The feature was surveyed acoustically on two occasions:
28 41.703N 88 13.530W 1 Aug 2010 163304
28 41.746N 88 13.426W 3 Aug 2010 091822

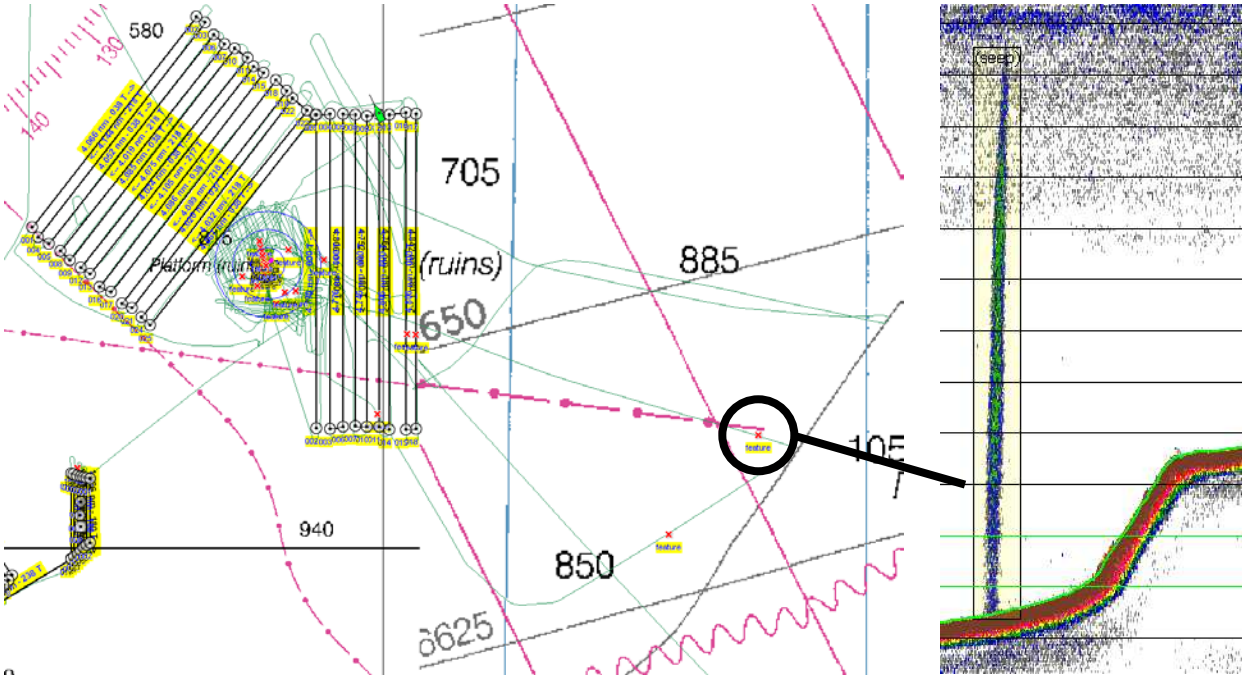


Figure 6. A) Map of all CTD stations sampled during cruise. B) Map of CTD stations sampled within vicinity of wellhead.

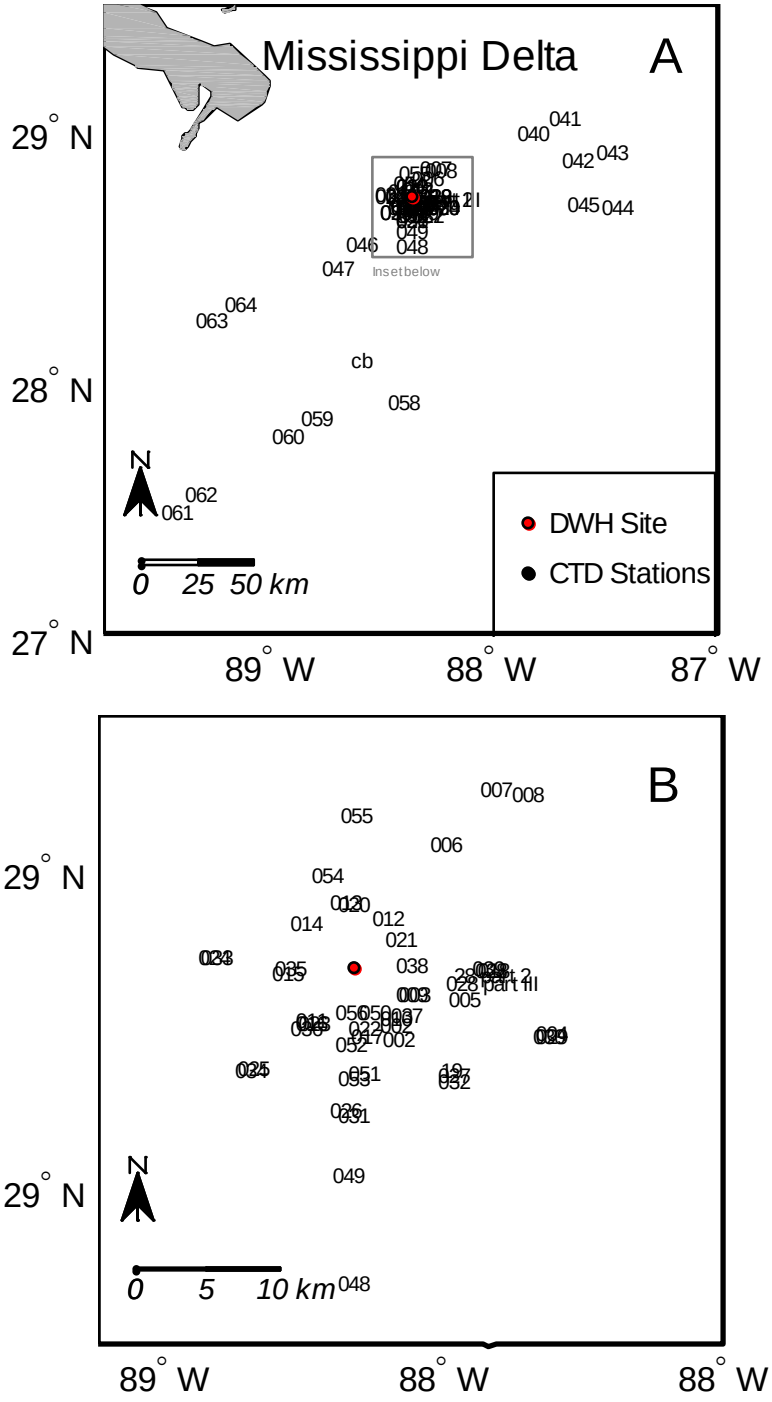


Figure 7. Profiles of dissolved oxygen. Data collected on Bigelow is in black. Data collected 2.5 months earlier on the Brooks McCall is in red. Data is preliminary.

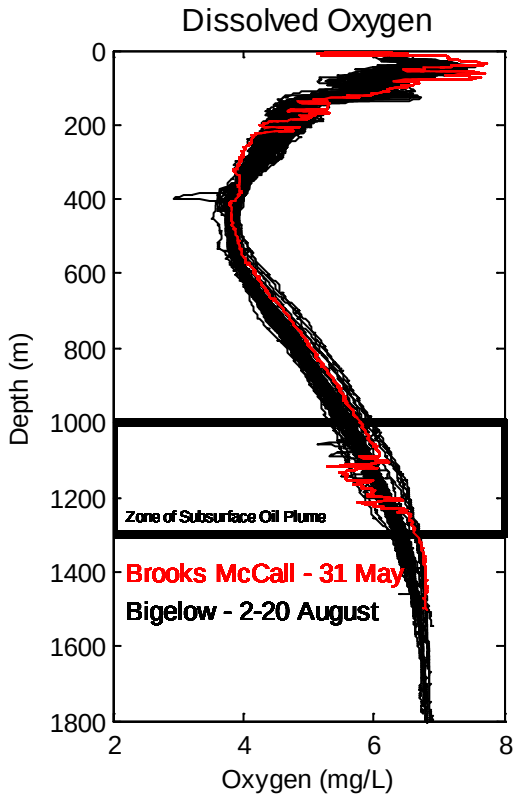


Figure 8. Profiles of colored dissolved organic matter. Data collected on Bigelow is in black. Data collected 2.5 months earlier on the Brooks McCall is in red. Data is preliminary.

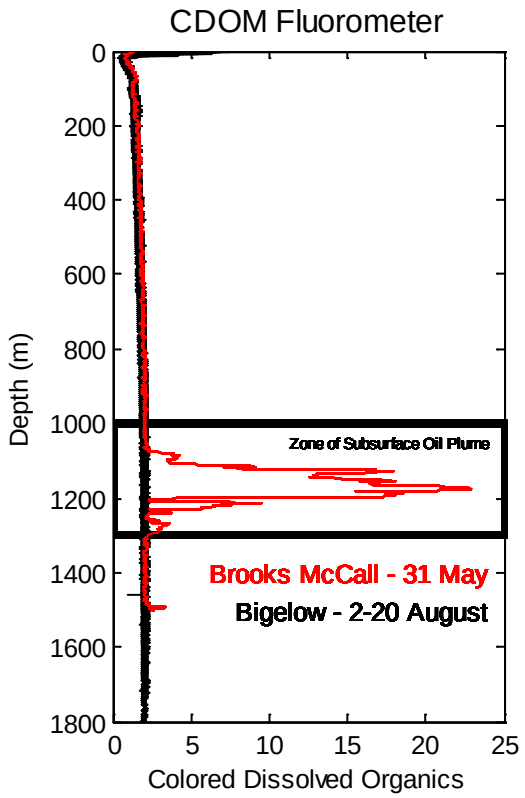


Figure 9. Profiles of temperature. Data collected on Bigelow is in black. Data is preliminary.

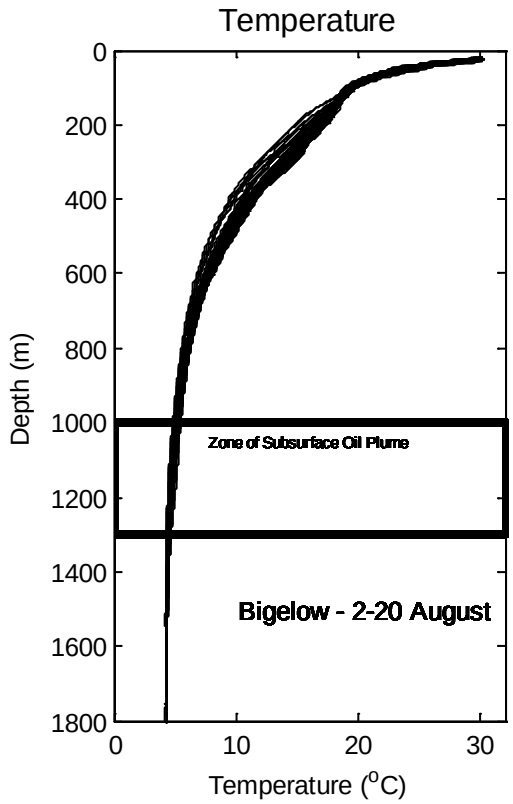


Figure 10. Profiles of salinity. Data collected on Bigelow is in black. Data is preliminary.

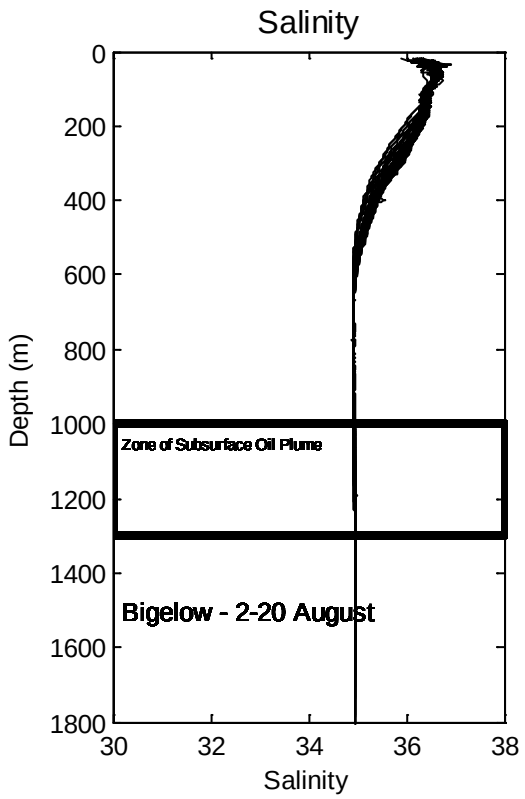


Figure 11. Comparison of dissolved oxygen concentrations determined using a membrane-based sensor on the CTD and a Winkler titration of water collected with the rosette attached to the CTD. Red line is 1:1. Black line is linear regression.

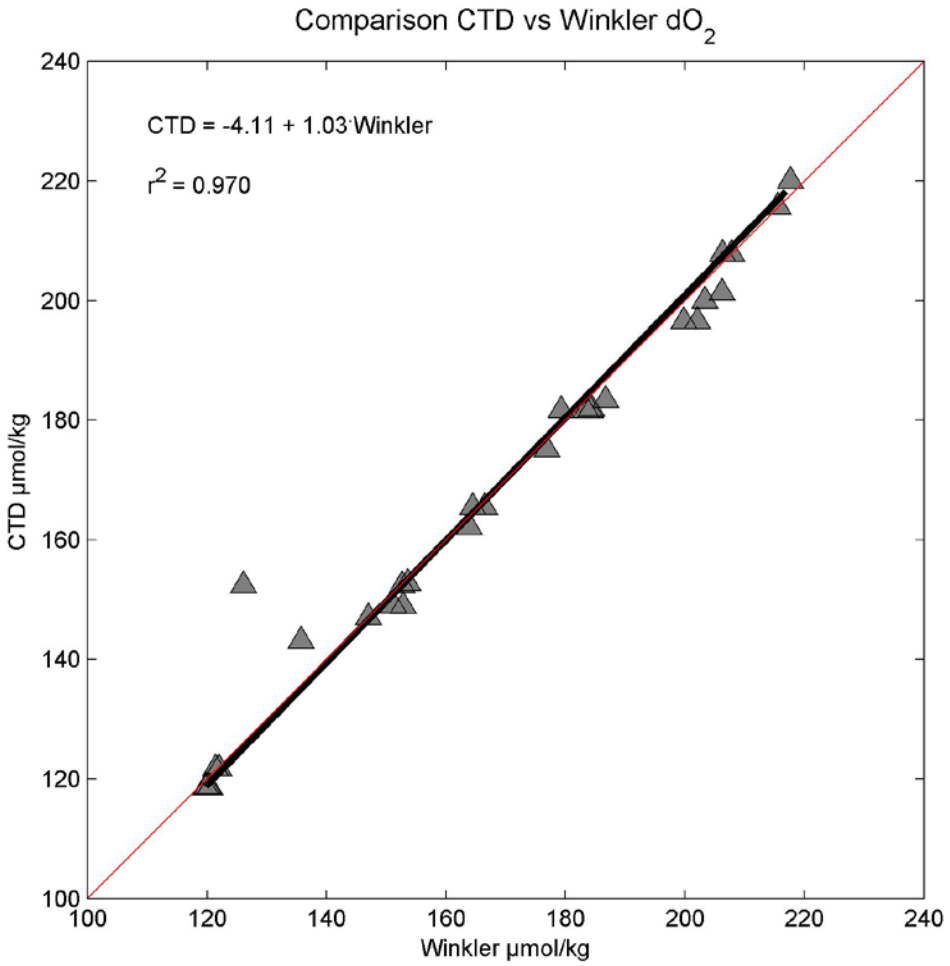


Figure 12. U.S. Naval Oceanographic Office autonomous gliders secured on deck aboard Henry B. Bigelow, August 19th, 2010.

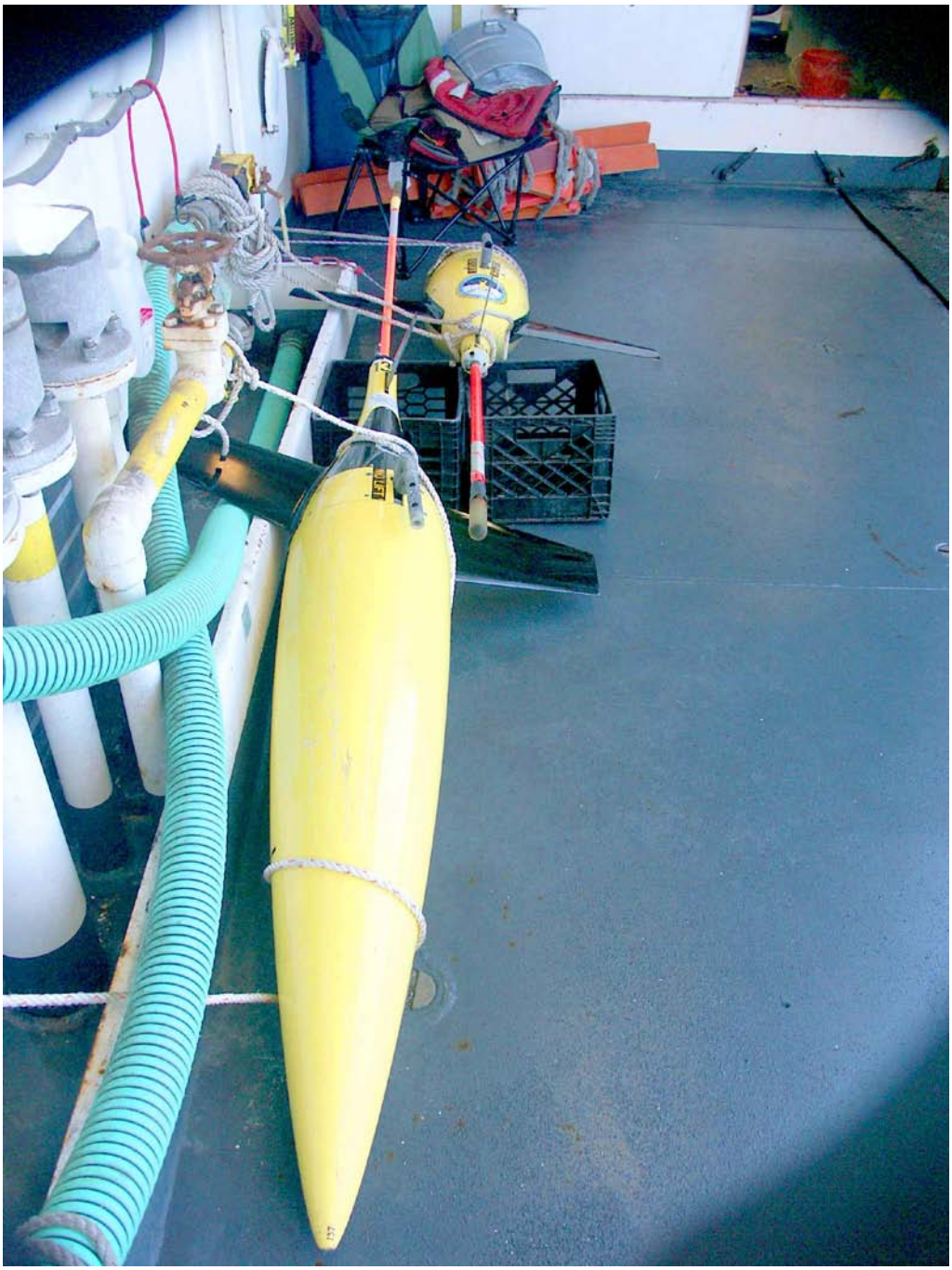
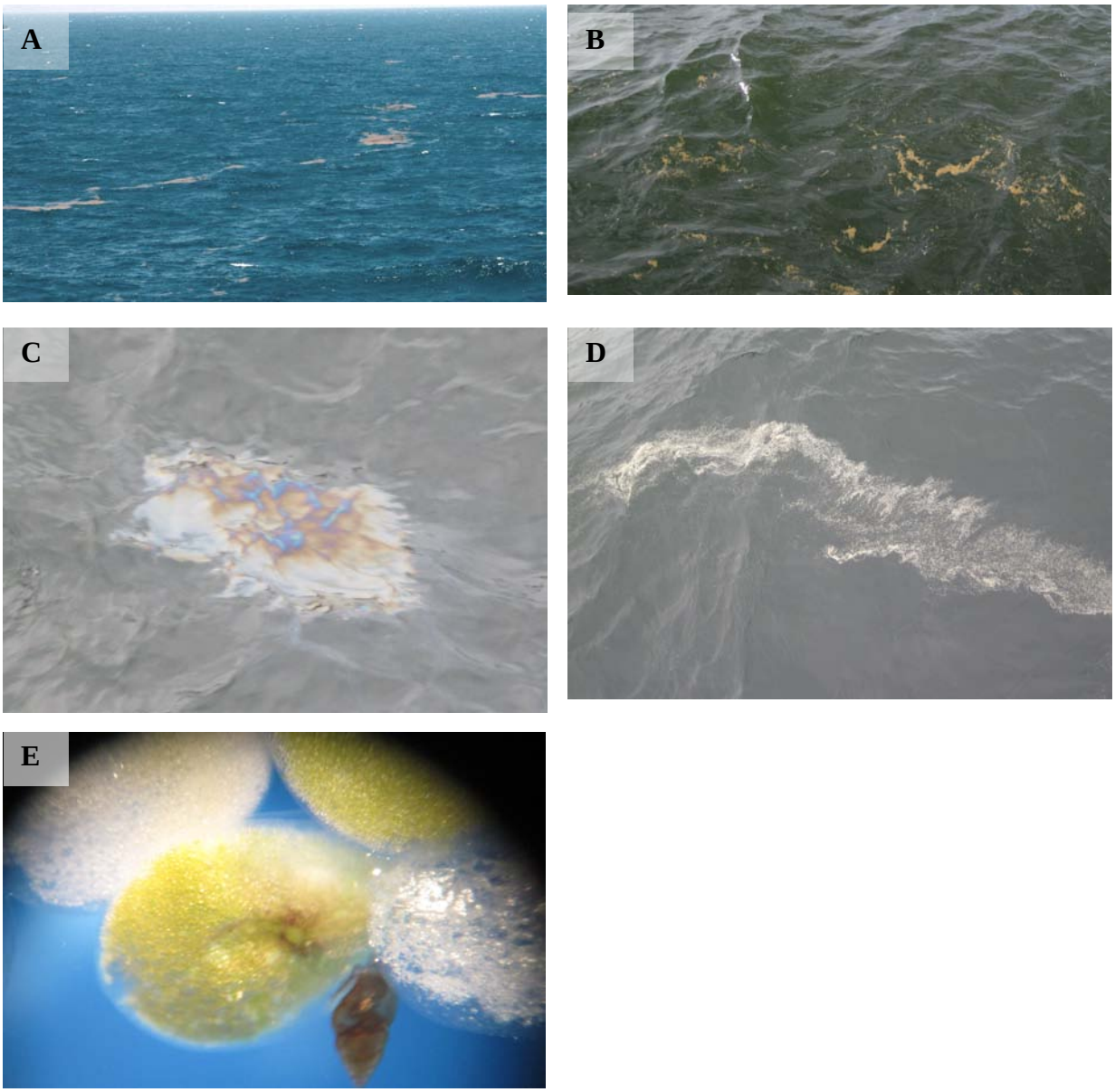


Figure 13. Surface observations: A) *Sargassum* rafts, B) Weathered oil, C) Oil sheen, D) Unidentified plant material, E) Unidentified plant material and snail under microscope (20 x).



Appendix 1 – Provided NRDA Water Sampling Protocols

Sampling Objectives

- To determine the concentration of oil compounds in the water column.
- To determine the source via fingerprinting, the degree of weathering, and background levels.
- To document exposure of water-column organisms and validate toxicity models.
- To maintain the integrity the sample(s) during sampling, transport, and storage.

Sample Volume

Analysis	***Sample Volume***	***Reporting Limit***
Volatile Aromatic Hydrocarbons (VAH)* by SIM GC/MS (collect in duplicate)	40 mL vials	0.1-1 µg/L (ppb)
Total Hydrocarbon (THC) by GC/FID	1-Liter	15 µg/L (ppb)
PAH (including alkylated PAHs) by SIM GC/MS	1-Liter	0.001 to 0.01 µg/L
Suface Oil Samples	Teflon Net	

*sometimes referred to as VOA or BTEX analysis

Sampling Equipment/Containers.

- Collect VAH samples (wearing clean Nitrile gloves) by pouring directly from the collection device (Niskin, Go-Flow bottle, or other sampler) into HCl-persevered 40 mL septum-capped vials. Ensure that there is no headspace (i.e., bubble) in the vial.
- Collect water samples for whole THC/PAH and filtered water in glass containers, certified-clean to be organic-free (solvent rinsed). Amber glass is preferred. Leave headspace of about 1 inch for 1 L jars.
- If slicks are present, decon samplers before each use (see separate QA Plan for the NRDA Cruise). Wash with laboratory-grade detergent and clean water, with a triple clean-water rinse (distilled water from a local store is OK but laboratory grade, certified-clean DI water is better. If that cannot be obtained, clean "background" water from an up-current non-contaminated area may be used. If sampler is contaminate by an oil slick, an Alkanox wash followed by solvent rinse with isopropanol (or acetone) and methylene chloride is appropriate. (See separate QA Plan for sampler decon and blank protocol/frequency.) Collect waste solvent rinsate for proper disposal.

Sample Collection Methods

- Collect subsurface samples below the water surface so as not to include any surface oil.

- Take “near surface” samples from approximately 1 m below the surface; take “near bottom” samples within 5 m of the bottom if possible.
- Sampling equipment MUST be deployed and retrieved in the closed position. Also applies to sample jars lowered by hand.
- On each cruise, try to sample the control/least oiled areas first, then more contaminated zones.
- Clear surface slicks with a boat hook or pole prior to deploying the equipment, but carefully so that the surface oil is not physically dispersed <u>into</u> the water column. Sweeping the area with sorbents or using a pressurized hose to move any surface oil before and after rosette deployment have been found to be effective techniques in the field.

- Surface oil samples (mousse, heavy sheen) can be collected using solvent-cleaned Teflon nets. The nets are most effective when deployed in combination with Nylon ring handles hoops which help secure the nets and provide a profile. Using clean tweezers or other method for secure removal (i.e. – surgical grade hemostats), remove the net from its container and gently position the Nylon ring handle inside the Teflon net. Using two clothespins or other devices, fold the upper corners of the net down and secure to the Nylon ring handle. Samples may be collected by casting to a specific location, or simply by lowering the net-ring assembly to the water level and dragging the assembly across the water surface and retrieving the sample. Remove the Teflon net and carefully place inside its original container. Nylon rings may be reused provided they have been decontaminated.

<u>Preservation/Holding Times</u>

- VAH (VOA vial): With no preservative the samples may be held for 7 days at 4°C in the dark. Addition of HCl can extend the holding time to 14 days at 4°C in the dark without loss of sample integrity.
- THC and PAH: No preservative added. Can be held at 4°C in the dark for up to 7 days.
- Immediately place all water samples in cooler and keep at 4° C (do not freeze).
- Use packing material around containers to prevent breakage.
- Ship to the laboratory ASAP with complete COCs. They need at least one day to process prior to holding time expiration.
- **Volatile hydrocarbons** (benzene, toluene, ethylbenzene, and xylene, or BTEX). For oil spill applications, the standard EPA Method 8240 (purge & trap) should be modified by running the GC/MS in selected ion monitoring mode and expanding the scan list (retention times and ions) to include the higher alkylated (C3 and C4) benzenes. Detection limits should be 1 ppb for individual analytes; 0.1 ppb is possible.
- **Total hydrocarbons** (THC). Often referred to as total petroleum hydrocarbons, but most methods do not differentiate among petroleum, petrogenic, and biogenic hydrocarbons. THC by GC-FID (total area of FID gas chromatogram of combined f_1 and f_2 fractions after column chromatography) is often the preferred method because

of the low detection limit (compared to other THC methods) and the direct measurement of individual hydrocarbons. This method does not detect low boiling compounds (below n-C_8). For NRDA, THC analyses generally will not provide the data needed to support calculation of toxic effects from PAH exposure, and will have to be corrected to equivalent PAHs. The THC results, however, can be used to tract oil weathering and map extent of exposure of water column resources, if meaningful detection limits can be reached. So, get a copy of the GC "trace." Detection limits are usually higher than those needed for aquatic injury assessment.

- **Polycyclic aromatic hydrocarbons** (PAH). Since most of the toxicity in oil is due to the PAHs, it is often the preferred analysis for NRDA. However, PAHs are expensive and require special laboratory skills. If PAHs are to be measured, it is important that the analytes include the alkyl-substituted PAH homologs, in addition to the standard PAH "priority pollutants." This method is referred to as Modified EPA Method 8270, because the list of PAHs is expanded to include the alkylated homologs, using GC/MS in the selected ion monitoring (SIM) mode. Detection levels should be 1 ppb for individual PAHs to support injury assessment using toxicity thresholds. Have the lab also run the source oil.

Other Considerations

- Contamination by surface slicks is of great concern. Document presence of slicks, weather, wave conditions, etc. which might suggest mixing of surface oil during sampling.
- Be aware of sources of contamination on the sampling vessel (exhaust fumes, engine cooling systems, oily surfaces). Work up-wind of any exhausts. Segregate dirty/clean areas. Lay out clean substrates to work on and replace frequently.
- Collect background samples from clean sites representative of pre-oiling conditions, as well as areas not yet oiled but in the potential path of the oil.
- Preservation chemicals should be provided by the lab.
- Use a computer or conceptual model of the extent of water-column contamination to determine the number and location of samples if available. Minimum guidelines are at least three samples per area of relatively uniform exposure or sub-waterbody. Sample along exposure gradients, starting in the cleanest zone, and sample at regular intervals proportional to the exposure area.

Contact James R. Payne at PECI for questions or additional information

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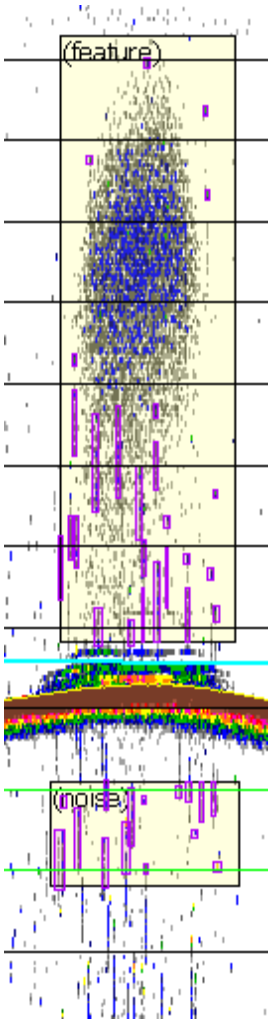
Appendix 2 - Procedure for Background Noise Correction of Wellhead Acoustic Data

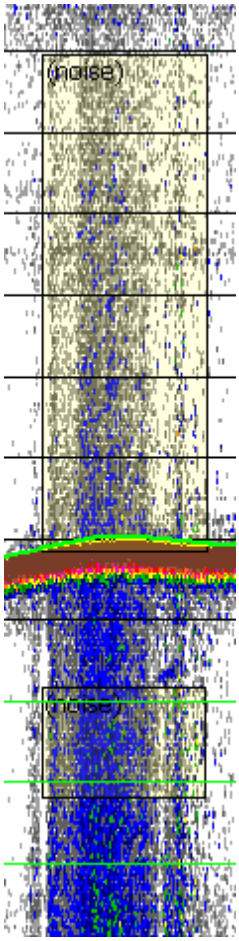
Prepared by Paul Walline, Alaska Fisheries Science Center

For each pass over the wellhead, a region was drawn on the echogram containing the plume/feature seen in the water column (Fig. A). A region of the same width was drawn below the surface covering the depth range between 1700 and 1800 m. In both types of regions, a regular noise feature consisting of tall stripes of a single ping's width could be seen. A region was drawn around each of these noise features and designated as bad data to remove it. The NASC (nautical area scattering coefficient, in units of $m^2 * nmi^{-2}$) of each region, both above and below the bottom, was calculated and output.

A.



B.



In another location, not over the wellhead, a noise feature starting at the bottom of the echogram and rising thru the echosounder identified bottom was observed (Fig. B). This looked very similar to the type of feature seen at the wellhead after the static kill. There

was no plume-like feature like that seen at the wellhead before the static kill (Fig.A). Ten of these features were identified and treated as described above for the wellhead features. Then a ratio was calculated between the NASC below the bottom and the NASC in the water column. Because the strength of the return of this noise signal increased with depth, it was necessary to create the sub-bottom region from 1800 to 1900 meters when the bottom depth reached 1600m. In those cases, the region for the water column feature was created to start deeper (1000m) and extend down to 1600m.
Once the ratio was determined it was used to remove noise from the wellhead features. The factor was 2.63, so the noise to be subtracted from NASC was 2.63 times the NASC of the sub-surface region. The results reduced the NASC for the passes made after the static kill to nearly zero, and in some cases to less than zero. The noise in the subsurface regions for the passes made on 7 August were especially high relative to the return in the feature in the water column, resulting in a large negative NASC. Apparently the relation developed elsewhere broke down for that date. Still, it seems clear that nearly all, if not all, the return after the static kill was noise, which was much higher after the kill than before. Before the kill, noise was much lower and there was a strong signal clearly detectable above the noise threshold.

Before	N	NASC	Corrected NASC	NASC*nmi	Corr. NASC*nmi	NASC*PI()*(nmi/2)^2	Corr. NASC * PI()*(nmi/2)^2
731	22	1904	1687	470	416	96	85
801	12	1162	861	416	303	122	87
802	15	1429	1114	454	357	121	95
average	49	1498	1221	447	358	113	89
After							
806	2	383	17	137	8	39	3
807	3	861	-290	284	-98	76	-27
808	16	539	90	159	28	37	7
809	8	439	-6	215	-2	84	0
average	4	556	-48	199	-16	59	-4

To account partially for the size of a feature, the NASC value was multiplied by the width of the feature in nmi. The width was taken as the distance between the start of the region containing it and the end of the region. Under the assumption that the features are cylindrical, ie isotropic, and that we passed thru the center, the total scattering content of the feature was determined by taking Pi times the square of half the distance calculated as described above. We are aware that with these data it is not possible to determine whether or not we passed over the center of a feature, but we followed nearly the same line across the feature at the wellhead for most of the passes we made, so this calculation can be of some use in comparing passes before and after the static kill.