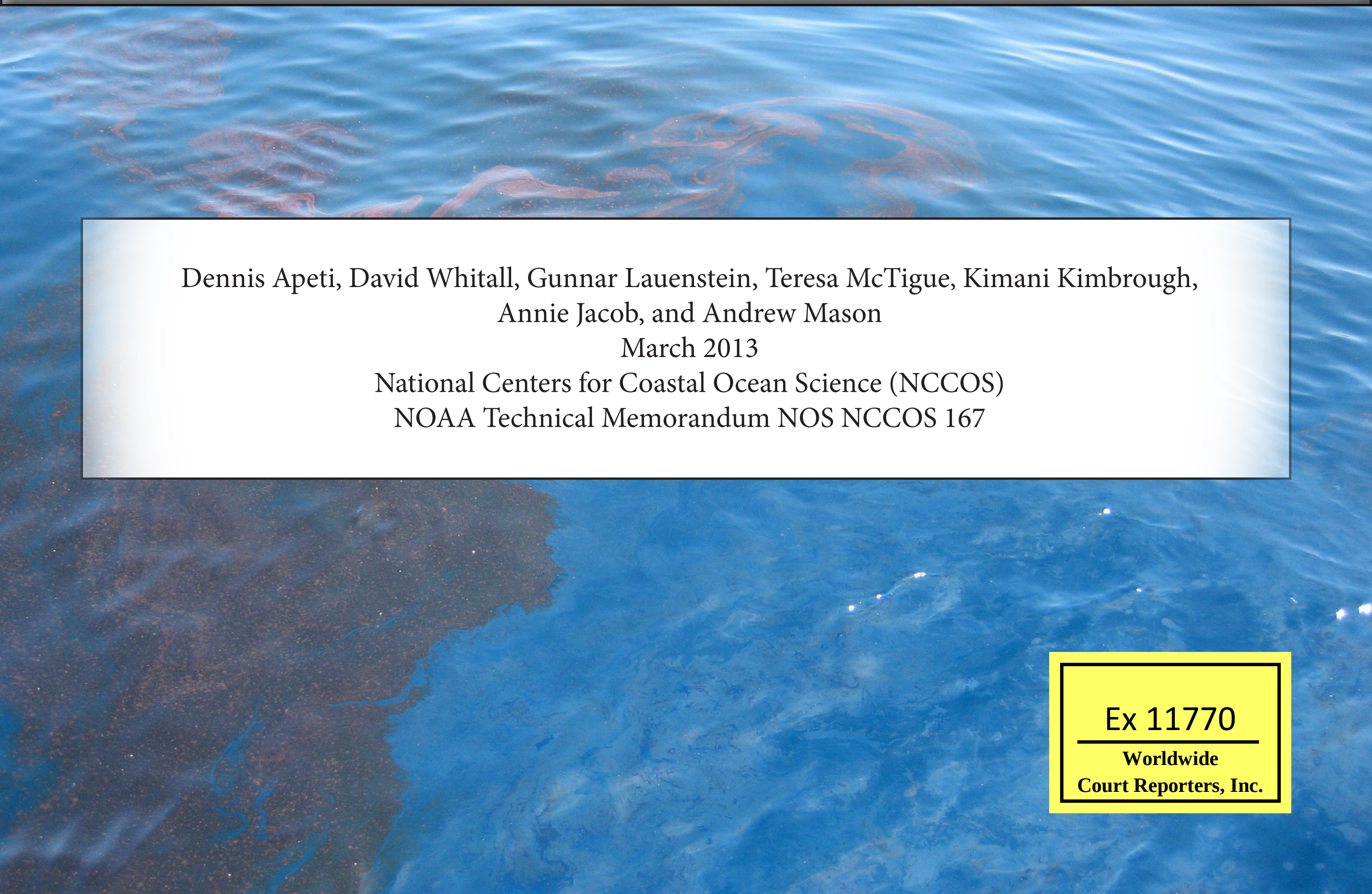
Assessing the Impacts of the Deepwater Horizon Oil Spill: The National Status and Trends Program Response

A Summary Report of Coastal Contamination



Dennis Apeti, David Whitall, Gunnar Lauenstein, Teresa McTigue, Kimani Kimbrough,
Annie Jacob, and Andrew Mason

March 2013
National Centers for Coastal Ocean Science (NCCOS)
NOAA Technical Memorandum NOS NCCOS 167

Mention of trade names or commercial products does not constitute endorsement or recommendation for their use by the United States government.

This report should be cited as: Apeti, D., D. Whitall, G. Lauenstein, T. McTigue, K. Kimbrough, A. Jacob, and A. Mason. 2013. Assessing the Impacts of the Deepwater Horizon Oil Spill: The National Status and Trends Program Response. A Summary Report of Coastal Contamination. NOAA Technical Memorandum NOS NCCOS 167. National Centers for Coastal Ocean Science (NCCOS), Center for Coastal Monitoring and Assessment (CCMA). Silver Spring, MD.

Assessing the Impacts of the Deepwater Horizon Oil Spill: The National Status and Trends Program Response

A Summary Report of Coastal Contamination

Dennis Apeti, David Whitall, Gunnar Lauenstein, Teresa McTigue, Kimani Kimbrough, Annie Jacob, and Andrew Mason

March 2013
National Centers for Coastal Ocean Science (NCCOS)
NOAA Technical Memorandum NOS NCCOS 167

Center for Coastal Monitoring and Assessment (CCMA)
Coastal Oceanographic Assessment of Status and Trends (COAST) Branch
1305 East-West Highway
Silver Spring, MD 20910

United States Department of Commerce	National Oceanic and Atmospheric Administration	National Ocean Service	National Centers for Coastal Ocean Science
Rebecca Blank Acting Secretary	Kathy Sullivan Acting Administrator	Holly Bamford Administrator	Mary C. Erickson Acting Director

Executive Summary

NOAA's National Status and Trends Program (NS&T) collected oyster tissue and sediments for quantification of polycyclic aromatic hydrocarbons (PAHs) and petroleum associated metals before and after the landfall of oil from the Deepwater Horizon incident of 2010. These new pre- and post- landfall measurements were put into a historical context by comparing them to data collected in the region over three decades during Mussel Watch monitoring.

Overall, the levels of PAHs in both sediment and oysters both pre- and post-landfall were within the range of historically observed values for the Gulf of Mexico. Some specific sites did have elevated PAH levels. While those locations generally correspond to areas in which oil reached coastal areas, it cannot be conclusively stated that the contamination is due to oiling from the Deepwater Horizon incident at these sites due to the survey nature of these sampling efforts. Instead, our data indicate locations along the coast where intensive investigation of hydrocarbon contamination should be undertaken.

Post-spill concentrations of oil-related trace metals (V, Hg, Ni) were generally within historically observed ranges for a given site, however, nickel and vanadium were elevated at some sites including areas in Mississippi Sound and Galveston, Terrebonne, Mobile, Pensacola, and Apalachicola Bays. No oyster tissue metal body burden exceeded any of the United States Food and Drug Administration's (FDA) shellfish permissible action levels for human consumption.

Introduction

The Deepwater Horizon incident of April 2010 caused an estimated 4.93 million barrels of crude oil to be spilled into the northern Gulf of Mexico over a span of three months (National Commission on BP DWH, 2011). Oil spills can have acute and chronic deleterious effects on biota and the environment as a result of chemical contamination. Major classes of oil-related compounds that can pose risks to biota are PAHs and heavy metals. Many PAHs are toxic and/or carcinogenic to humans and wildlife (Eisler, 1987; ATSDR, 1995 and 2009). Toxic metals such arsenic, cadmium, chromium, iron, manganese, mercury, and selenium are also present in crude oil in trace amounts (Nadkarni, 1991). However, the most prevalent oil-related metals are vanadium, nickel, and mercury, which can cause ecosystem damage at high concentrations (Nadkarni, 1991; Osuji and Achugasim, 2010).

Since 1986, the National Centers for Coastal Ocean Science (NCCOS) Mussel Watch Program (MWP) has monitored the concentration and distribution of more than 400 contaminants in U.S. waters. These contaminants include but are not limited to metals, legacy organics, PAHs, and selected contaminants of emerging concern. Over 300 sites are monitored nationwide, with bivalves collected biennially and sediment collected on a decadal frequency (Kimbrough et al., 2008). To assess the potential impacts of the Deepwater Horizon oil spill on the coastal zone of the Gulf of Mexico, NCCOS collected and analyzed sediment and oyster samples at long-term MWP monitoring sites, both before and after the spilled oil made landfall. The MWP has previously used its long-term monitoring data as a baseline to assess environmental changes in the aftermath of other catastrophic environmental disasters including Hurricanes Katrina and Rita, the attack on the World Trade Center, and several oil spills including the 2004 Athos-I spill in Delaware Bay and the 2007 Cosco Busan spill in San Francisco (Kimbrough et al., 2010; Johnson et al., 2008; Lauenstein and Kimbrough, 2007). Notably, for the Deepwater Horizon oil spill event, the Operational Science Advisory Team highlighted the Mussel Watch Program as one of the two sources for pre-impact PAH data for the Gulf of Mexico (OSAT, 2010).

In this report, we provide an assessment of the Deepwater Horizon oil spill impacts on the coastal zone along the northern Gulf of Mexico using PAHs and metals concentrations in oyster tissue and sediment. The MWP's historical monitoring data were used to provide baseline concentrations against which the magnitude and extent of coastal contamination from the Deepwater Horizon oil spill is assessed.

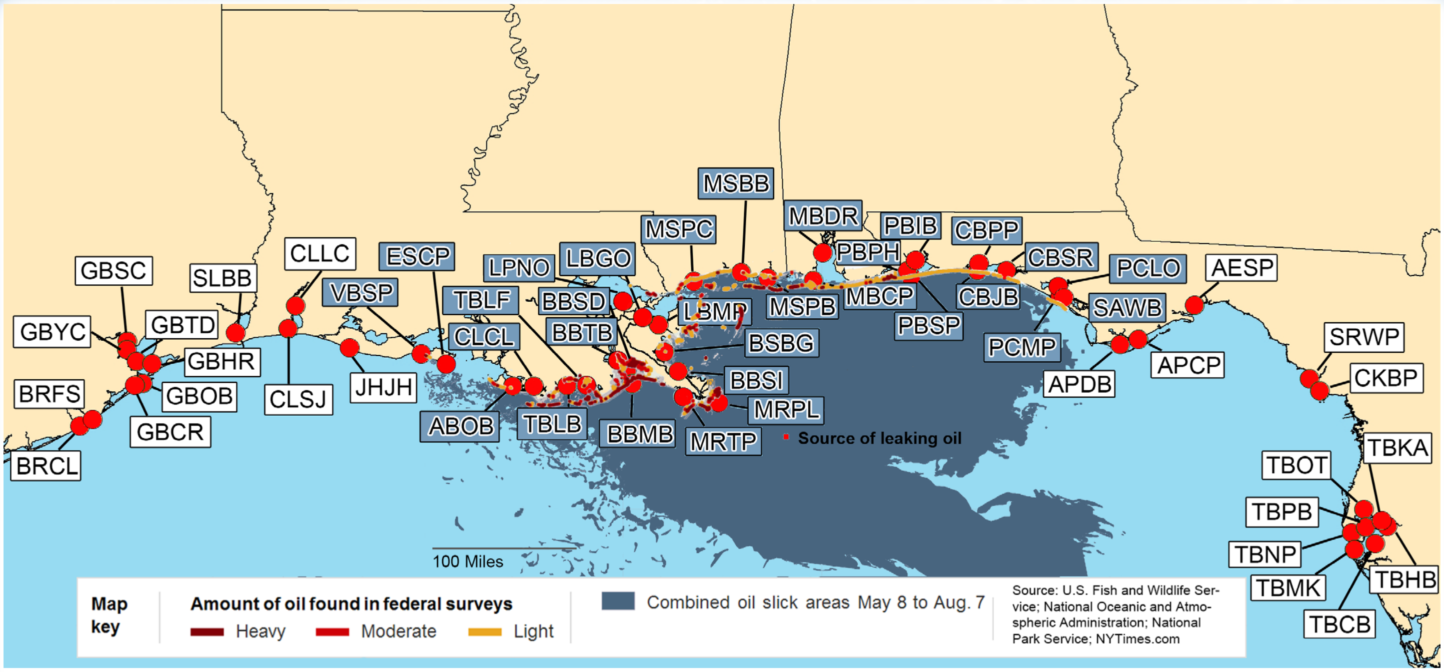


Figure 1. Map depicting locations of Mussel Watch contaminant monitoring sites sampled in May and November, 2010 for the Deepwater Horizon coastal contamination assessment. Shaded area depicts the combined oil slick area. Monitoring sites within the potentially oiled coastal areas are highlighted. Sources: U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration and National Park Service.

Table 1. Mussel Watch long-term contaminant monitoring sites sampled in May and November, 2010 for the Deepwater Horizon coastal contamination assessment. Sites are arranged alphabetically and by state from west to east. O = oysters (*Crassostrea virginica*), S = sediment.

Code	Site	May-10		Nov-10	
		O	S	O	S
BRFS	Brazos River, Freeport Surfside		x		x
BRCL	Brazos River, Cedar Lake	x	x	x	x
GBYC	Galveston Bay, Yacht Club	x	x	x	x
GBSC	Galveston Bay, Ship Channel	x	x	x	x
GBTD	Galveston Bay, Todd's Dump	x	x	x	x
GBHR	Galveston Bay, Hanna Reef		x		x
GBOB	Galveston Bay, Offatts Bayou		x		x
GBCR	Galveston Bay, Confederate Reef	x	x	x	x
SLBB	Sabine Lake, Blue Buck Point		x		x
CLLC	Calcasieu Lake, Lake Charles	x	x	x	x
CLSJ	Calcasieu Lake, St. Johns Island				x
JHJH	Joseph Harbor				x
VBSP	Vermilion Bay, Southwest Pass	x		x	x
ESCP	East Cote Blanche, South Point				x
CLCL	Caillou Lake	x	x	x	x
TBLB	Terrebonne Bay, Lake Barre	x	x	x	x
TBLF	Terrebonne Bay, Lake Felicity		x		x
BBMB	Barataria Bay, Middle Bank	x	x	x	x
BBTB	Barataria Bay, Turtle Bay		x		x
BBSD	Barataria Bay, Bayou Saint Denis	x	x	x	x
MRTP	Mississippi River, Tiger Pass				x
MRPL	Mississippi River, Pass A Loutre				x
BSSI	Breton Sound, Sable Island		x		x
BSBG	Breton Sound, Bay Gardene		x		x
LPNO	Lake Pontchartrain, New Orleans				x
LBGO	Lake Borgne, Gulf Outlet				x
MSPC	Mississippi Sound, Pass Christian	x		x	
MSBB	Mississippi Sound, Biloxi Bay	x		x	
MSPB	Mississippi Sound, Pascagoula Bay	x		x	
MBCP	Mobile Bay, Cedar Point Reef	x		x	
MBDR	Mobile Bay, Dog River	x		x	
PBPH	Pensacola Bay, Public Harbor	x		x	
PBSP	Pensacola Bay, Sabine Point	x		x	
PBIB	Pensacola Bay, Indian Bayou	x		x	
CBPP	Choctawhatchee Bay, Postil Point	x		x	
CBJB	Choctawhatchee Bay, Joe's Bayou	x	x	x	x
PCMP	Panama City, Municipal Pier	x	x	x	x
PCLO	Panama City, Little Oyster Bar	x		x	x
SAWB	St. Andrews Bay, Watson Bayou	x	x	x	x
APDB	Apalachicola Bay, Dry Bar	x	x	x	x
APCP	Apalachicola Bay, Cat Point Bar	x	x	x	x
SRWP	Suwannee River, West Pass	x		x	
CKBP	Cedar Key, Black Point	x		x	
TBNP	Tampa Bay, Navarez Park	x		x	
TBMK	Tampa Bay, Mullet Key Bayou	x		x	

Sample Collection and Analysis

Mussel Watch has 86 long-term sites in the Gulf region. Based on NOAA's initial projections of spill trajectory and the determination of the Natural Resource Damage Assessment (NRDA) Topical Working Group (TWG), a subset of the long-term sites in the coastal zone that could be potentially oiled (Figure 1) was determined, covering the areas from the Brazos River in Texas to Tampa Bay, Florida. Due to logistics and TWG directives, a total of 23 sites were sampled for sediment and a total of 30 sites were sampled for oysters (*Crassostrea virginica*) and/or sediment in May 2010 (pre-landfall) and November 2010 (post-landfall). Ultimately, DWH related oil slicks did not make landfall near all sampling sites (Figure 1).

Surface sediments (top 1 - 2 cm fraction to represent newly deposited materials) and oyster specimens were collected using standard NS&T procedures (Lauenstein and Cantillo, 1998). The samples were handled using strict documentation and chain-of-custody procedures based on the NOAA's National Resources Damage Assessment (NRDA) process (http://nrdata.org/).

Both oyster tissue and sediment samples were analyzed for PAHs (Table 2). Sediment samples were not measured for metals because of insufficient funding and negligible concentration changes that may result from the exposure to oil. Oyster tissue samples from November were analyzed for trace elements (Table 2), in partnership with the FDA. Thus, our spill impacts assessment for metal contamination were limited to comparing the post-landfall results in tissue to those of the historical monitoring data. Site-specific assessments were made comparing post-landfall concentrations to the long-term data range (from 1986 – 2009) for each metal. Vanadium, a crude oil signature metal, is not routinely measured by the MWP so archived samples from the years 2008 and 2009 were analyzed to allow for comparison between pre- and post- spill samples. In addition to the PAHs and metals, oyster tissue samples were measured for ancillary parameters such as moisture and lipid content while sediment samples were analyzed for total inorganic carbon and grain size. All chemical analyses followed NS&T methods documented in Lauenstein and Cantillo, (1998), Kimbrough and Lauenstein (2006) Kimbrough et al. (2007), and McDonald et al. (2006).

Physiological processes, such as gametogenesis and spawning, can significantly influence the contaminant body burdens of oysters (Mix et al., 1982). Lipophilic compounds such as hydrocarbons tend to be preferentially concentrated in gonadal tissue which may account for up to 50% of the soft tissue (Choi et al., 1993). Thus, a subset of oysters collected from each monitoring site were examined for the state of gonadal development (gonadal index) to give an indication of the amount of gametic material in the tissues at the time of chemical analysis. Standard procedures for gonadal index characterization in bivalves are detailed in Kim et al. (2006). Oysters collected in May were mostly in 'late development', 'fully developed' and/or spawning with visible gametes, whereas oysters collected in November were mostly sexually undifferentiated or spawning with few or no gametes visible and, as such, are considered post-spawning. Because of this distinct difference in the stage of gametogenesis between pre- and post-landfall samples coupled with the fact that organic contaminants preferentially accumulate in lipids, the total PAH concentrations were normalized on the lipid fraction so as to facilitate comparison between the obtained values from two different times of the year. However, the November post-landfall samples are physiologically comparable to long-term Mussel Watch bivalve samples, which are always collected post-spawning and was compared as such with historic measurements.

Table 2. Individual PAH compounds used to compute total PAHs and oil-related metals measured as a part of this assessment. Metals discussed as part of this document are in bold. For simplicity, the term metal is used without distinction between true metals and metalloids.

PAHs		Metals
Biphenyl	Dibenzothiophene	Arsenic (As)
Naphthalene	C1-Dibenzothiophenes	Cadmium (Cd)
C1-Naphthalenes	C2-Dibenzothiophenes	Chromium (Cr)
C2-Naphthalenes	C3-Dibenzothiophenes	Copper (Cu)
C3-Naphthalenes	Fluoranthene	Iron (Fe)
C4-Naphthalenes	C1-Fluoranthenes/Pyrenes	**Mercury (Hg)**
Acenaphthylene	Benz[a]anthracene	Manganese (Mn)
Acenaphthene	Chrysene/Triphenylene	**Nickel (Ni)**
Fluorene	C1-Chrysenes	Lead (Pb)
C1-Fluorenes	C2-Chrysenes	Antimony (Sb)
C2-Fluorenes	C3-Chrysenes	Selenium (Se)
C3-Fluorenes	C4-Chrysenes	Zinc (Zn)
Anthracene	Benzo[b]fluoranthene	**Vanadium (V)**
Phenanthrene	Benzo[j,k]fluoranthene	
C1-Phenanthrenes/Anthracenes	Benzo[e]pyrene	
C2-Phenanthrenes/Anthracenes	Benzo[a]pyrene	
C3-Phenanthrenes/Anthracenes	Dibenzo[a,h]anthracene	
C4-Phenanthrenes/Anthracenes	Benzo[g,h,i]perylene	
Pyrene	Indeno[1,2,3-c,d]pyrene	

Results and Discussion

Polycyclic Aromatic Hydrocarbons (PAHs)

Key Large Scale Findings of PAHs in Sediments

- The median concentration of post-landfall measurements is well below the national median (Figure 2).
- Post- landfall measurements are comparable to measurements in the region in 2006/2007.
- Based on the overall magnitude of total PAHs, there is no conclusive evidence of an increase in Gulf-wide PAH coastal sediment contamination from the Deepwater Horizon oil spill at Mussel Watch sites. A site-specific analysis does show areas of concern regarding PAHs and is presented later in the report.

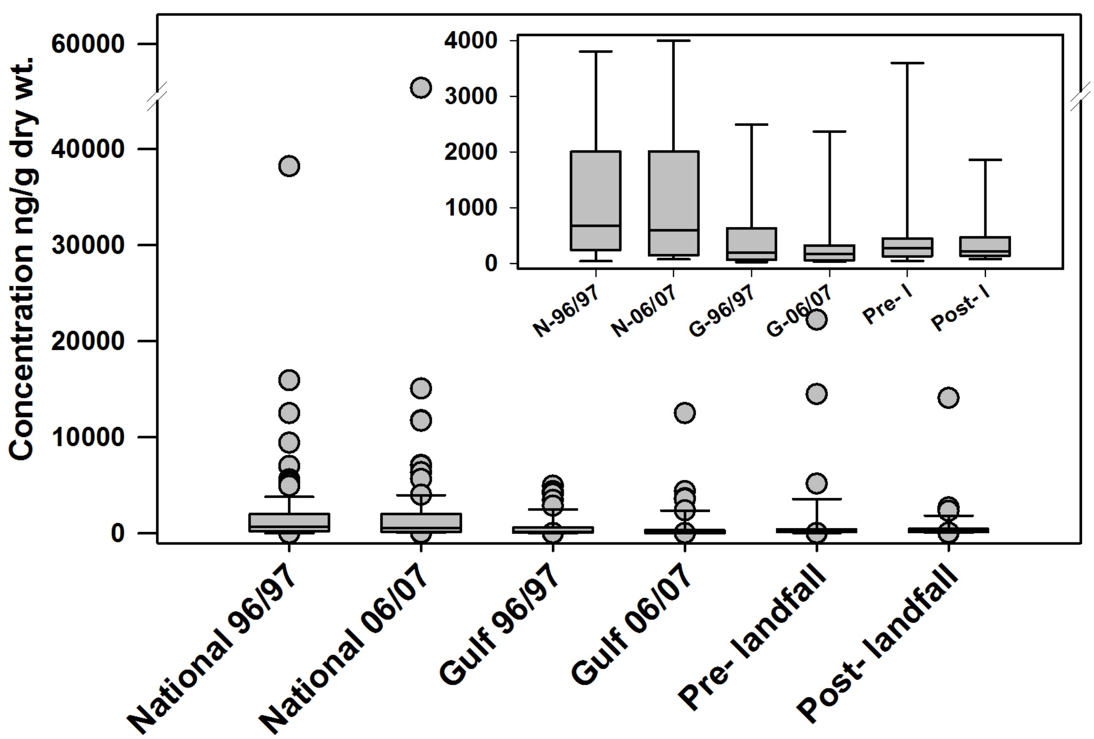


Figure 2. Comparison of pre- and post-landfall total PAH measurements in sediments collected from the coastal zone of the Gulf of Mexico in the aftermath of Deepwater Horizon oil spill to historic measurements collected by NOAA Mussel Watch Program. 'National' ('N' in inset) refers to sediment collected from Mussel Watch sites around the country other than Gulf, 'Gulf' ('G' in inset) refers to sediment collected solely from the Gulf of Mexico, 'Pre- landfall' ('Pre- l' in inset) refers to sediment collected from Gulf of Mexico in May 2010 and 'Post- landfall' ('Post- l' in inset) refers to sediment collected from the Gulf of Mexico in November 2010. The inset figure depicts the same data without outliers. The bottom and top of the boxplots represent the 25th and 75th percentiles respectively, the whiskers represent the 5th and 95th percentiles, the dots represent outliers that lie beyond the 5th and 95th percentiles, and the line in the middle of the box is the median.

Key Large Scale Findings of PAHs in Oysters

- Gulf-wide post-landfall tissue concentrations fall within the range of historic measurements (Figure 3).

- Based on the overall magnitude of total PAHs in oyster tissues, there is no conclusive evidence of an increase in tissue burden in oysters from Mussel Watch sites around the coastline of the Gulf of Mexico following Deepwater Horizon oil spill.

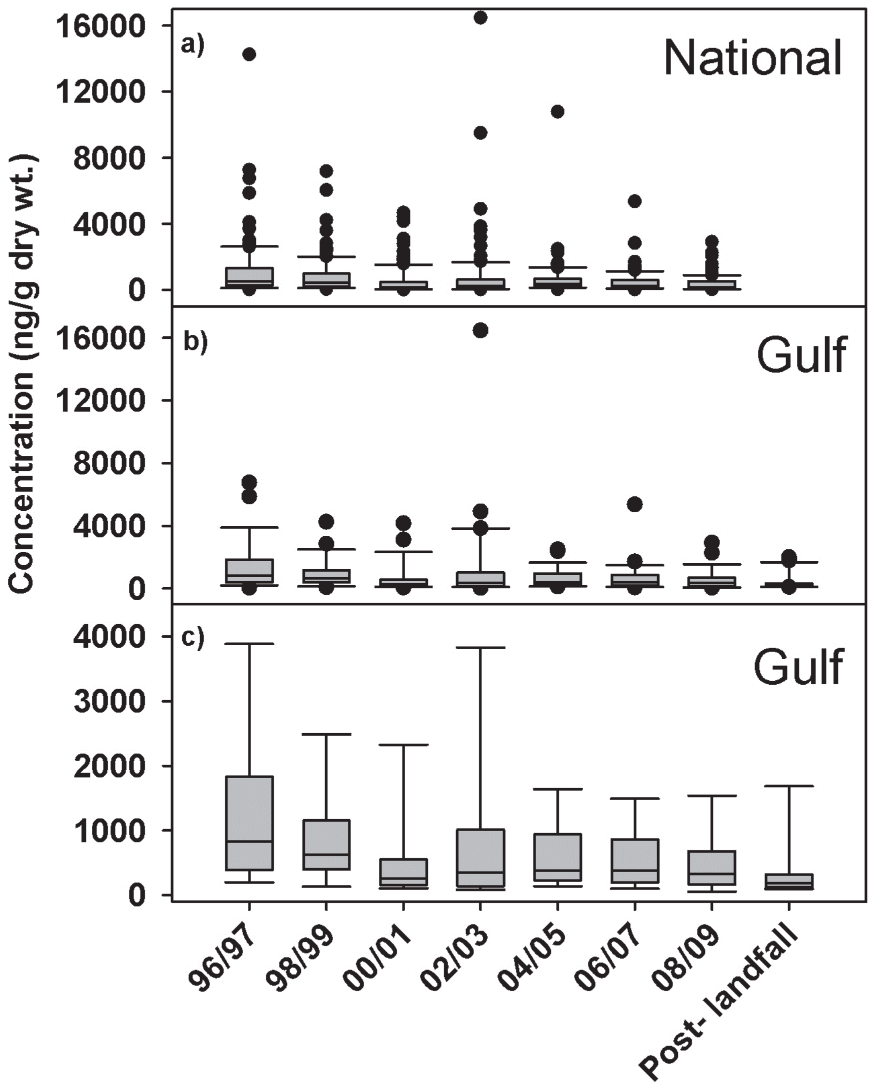


Figure 3. Comparison of post-landfall total PAHs (sum of 38 individual compounds) measurements in the tissues of oysters collected in Nov 2010 from the coastal zone of the Gulf of Mexico in the aftermath of the Deepwater Horizon oil spill to historic measurements collected by NOAA's Mussel Watch Program. 'National' (Fig. 4a.) depicts the overall trends in total PAH concentrations in oysters collected from the Gulf of Mexico, Middle Atlantic and Southeast Atlantic from 1996-2009. 'Gulf' depicts the overall trends in total PAH concentrations in oysters collected from 30 sites from the Gulf of Mexico for the Deepwater Horizon oil spill assessment with (Fig. 3b.) and without (Fig. 3c.) outliers. The bottom and top of the boxplots represent the 25th and 75th percentiles respectively, the whiskers represent the 5th and 95th percentiles, the dots represent outliers that lie beyond the 5th and 95th percentiles, and the line in the middle of the box is the median.

Key Findings from Pre- and Post-Landfall Lipid-Normalized Oyster Tissue PAH Analysis

- The lipid-normalized total PAH (Figure 4) concentrations in oysters indicated that post-landfall measurements at the site BBMB in Barataria Bay, Louisiana and at the SAWB site in St. Andrews Bay in Florida were substantially higher than pre-landfall measurements.

- Sites BBMB and SAWB were in coastal areas where spilled oil reached the shoreline (Figure 1). Further research is warranted to explain these observations.

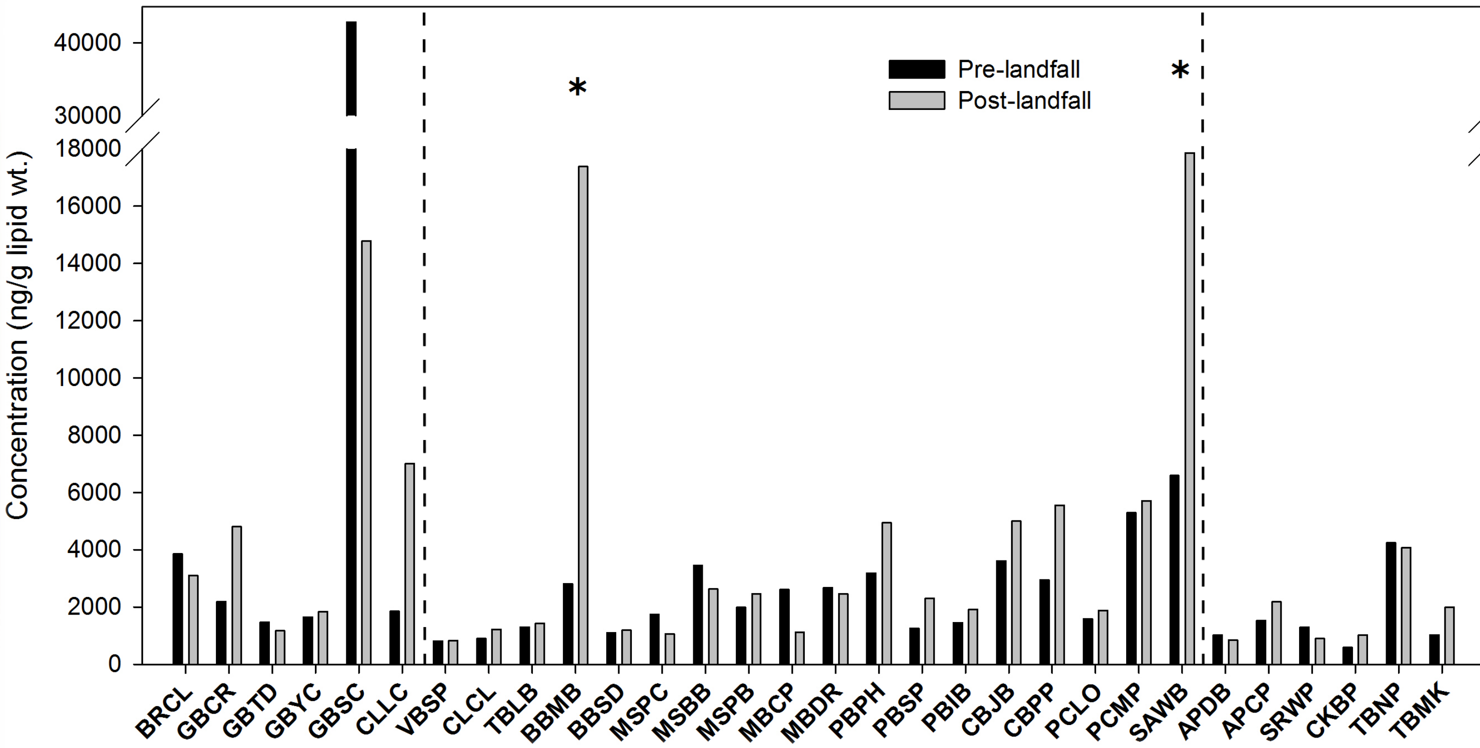


Figure 4. Bar chart depicting pre- and post-landfall lipid normalized total PAH concentrations (ng/g lipid wt.) in oyster tissue from select Mussel Watch sites in the coastal zone of the Gulf of Mexico. The sites within the potentially oiled zone lie between the two dotted lines from site VBSP to site SAWB. Sites BBMB and SAWB (*) had substantially higher post-landfall PAH concentrations than pre-landfall measurements.

Key Findings from Site Specific Oyster Tissue PAH Analysis

- The post-landfall total PAH concentrations at the majority of sites are comparable to historic measurements (Table 3).

- The highest concentrations (marked in red) were found at the Middle Bank in Barataria Bay, Louisiana (site BBMB), the Watson Bayou in St. Andrews Bay, Florida (site SAWB) and the Ship Channel in Galveston Bay, Texas (site GBSC; located outside potentially oiled zone). The post-landfall concentration at site BBMB is much higher than the site-specific concentrations of recent years, although not the highest concentration ever observed at that site. The Watson Bayou site is located near a small shipyard and the Ship Channel in Galveston Bay sees extensive vessel traffic. Both locations could have PAH impacts independent of the Deepwater Horizon spill. Further sampling is urged at all four locations to better understand these patterns.

Key Findings from Site Specific Sediment PAH Analysis

- Based on site-specific concentrations listed in Table 4, the majority of sites have concentrations that are comparable to historic measurements.

- The sites that have relatively higher post-landfall concentrations compared to pre-landfall concentrations are marked in red: SLBB in Sabine Lake, Texas and PCMP at the Municipal Pier in Panama City.

- NS&T site SLBB is outside the potential oiling zone identified in Figure 1.

- Site PCMP was potentially oiled, but the survey nature of these sampling efforts make it difficult to form conclusive evidence of oiling based on May and Nov 2010 concentrations. Intensive sampling should be conducted at this site. It also appears that the May 2010 concentration was significantly lower than what was historically observed, potentially due to flushing events due to seasonal rainfall and tidal patterns, and may not be representative.

Table 3. Historic PAH concentrations (ng/g dry weight) in oyster tissue from the Gulf of Mexico. Grey rows denote sites within the potentially oiled zone as depicted in Fig. 1. Values in red denote large differences in concentration between data from November 2010 and historical data.

Site	General Location	Specific Location	State	96/97	98/99	00/01	02/03	04/05	06/07	08/09	Nov-10
BRCL	Brazos River	Cedar Lakes	TX	823	509	594	496	947	686	-	183
GBCR	Galveston Bay	Confederate Reef	TX	711	491	625	333	583	434	380	333
GBTD	Galveston Bay	Todd's Dump	TX	877	1104	557	2079	1639	864	177	134
GBYC	Galveston Bay	Yacht Club	TX	1356	1763	2327	1076	2490	517	518	298
GBSC	Galveston Bay	Ship Channel	TX	-	2343	4161	3623	-	1711	810	1994
CLLC	Calcasieu Lake	Lake Charles	LA	2636	564	234	3198	932	1466	2271	710
VBSP	Vermilion Bay	Southwest Pass	LA	421	562	119	380	286	189	212	107
CLCL	Caillou Lake	Caillou Lake	LA	46	521	324	217	241	279	49	97
TBLB	Terrebonne Bay	Lake Barre	LA	470	79	55	49	218	197	73	94
BBMB	Barataria Bay	Middle Bank	LA	2056	965	378	850	705	331	183	1793
BBSD	Barataria Bay	Bayou Saint Denis	LA	290	493	117	360	423	268	162	137
MSPC	Mississippi Sound	Pass Christian	MS	367	2839	188	455	595	5368	646	91
MSBB	Mississippi Sound	Biloxi Bay	MS	-	4244	188	3851	924	866	683	213
MSPB	Mississippi Sound	Pascagoula Bay	MS	366	379	139	318	368	576	553	306
MBCP	Mobile Bay	Cedar Point Reef	AL	826	156	228	142	190	204	184	124
MBDR	Mobile Bay	Dog River	AL	2742	1423	549	790	1166	939	1022	307
PBPH	Pensacola Bay	Public Harbor	FL	1754	1204	261	307	357	566	566	445
PBSP	Pensacola Bay	Sabine Point	FL	721	132	191	80	187	198	-	131
PBIB	Pensacola Bay	Indian Bayou	FL	-	626	105	33	138	174	194	176
CBJB	Choctawhatchee Bay	Joe's Bayou	FL	3032	2487	493	16477	2371	1267	1357	285
CBPP	Choctawhatchee Bay	Postil Point	FL	1447	1092	284	708	446	306	325	317
PCLO	Panama City	Little Oyster Bar	FL	448	861	180	196	358	-	-	189
PCMP	Panama City	Municipal Pier	FL	5865	241	2026	992	1356	-	2914	342
SAWB	St. Andrews Bay	Watson Bayou	FL	6753	1071	3106	4905	1205	1445	475	1877
APDB	Apalachicola Bay	Dry Bar	FL	266	1027	146	101	336	122	58	113
APCP	Apalachicola Bay	Cat Point Bar	FL	929	330	346	130	335	263	330	215
SRWP	Suwannee River	West Pass	FL	-	-	-	152	192	103	55	110
CKBP	Cedar Key	Black Point	FL	40	413	106	110	127	73	52	104
TBNP	Tampa Bay	Navarez Park	FL	1291	653	394	221	376	766	682	188
TBMK	Tampa Bay	Mullet Key Bayou	FL	395	104	169	118	116	89	141	136

Table 4. Historic PAH concentrations (ng/g dry weight) in sediment from the Gulf of Mexico. Grey rows denote sites within the potentially oiled zone depicted in Fig. 1. Values in red denote large changes in concentration from May to November.

Site	General Location	Specific Location	State	Gulf 96/97	Gulf 06/07	May-10	Nov-10
BRCL	Brazos River	Cedar Lakes	TX	294	359	251	141
BRFS	Brazos River	Freeport Surfside	TX	4109	920	143	154
GBCR	Galveston Bay	Confederate Reef	TX	286	284	379	195
GBOB	Galveston Bay	Offatts Bayou	TX	3475	12509	14489	14086
GBTD	Galveston Bay	Todd's Dump	TX	183	326	183	33
GBYC	Galveston Bay	Yacht Club	TX	51	179	170	159
GBSC	Galveston Bay	Ship Channel	TX	-	1276	693	653
GBHR	Galveston Bay	Hanna Reef	TX	191	236	224	230
SLBB	Sabine Lake	Blue Buck Point	LA	40	183	**82**	**742**
CLSJ	Calcasieu Lake	St. Johns Island	LA	65	542	-	134
CLLC	Calcasieu Lake	Lake Charles	LA	297	263	383	263
JHJH	Joseph Harbor Bayou	Joseph Harbor Bayou	LA	122	356	-	33
VBSP	Vermilion Bay	Southwest Pass	LA	-	56	-	80
ECSP	East Cote Blanche	South Point	LA	-	-	-	303
CLCL	Caillou Lake	Caillou Lake	LA	81	203	367	105
TBLB	Terrebonne Bay	Lake Barre	LA	132	-	296	181
TBLF	Terrebonne Bay	Lake Felicity	LA	137	-	242	267
BBMB	Barataria Bay	Middle Bank	LA	480	723	425	652
BBSD	Barataria Bay	Bayou Saint Denis	LA	150	166	283	72
BBTB	Barataria Bay	Turtle Bay	LA	-	-	327	343
MRTP	Mississippi River	Tiger Pass	LA	1241	-	-	104
MRPL	Mississippi River	Pass A Loutre	LA	631	-	-	371
BSSI	Breton Sound	Sable Island	LA	651	-	864	504
BSBG	Breton Sound	Bay Gardene	LA	126	-	344	106
LBGO	Lake Borgne	Gulf Outlet	LA	-	-	-	297
LPNO	Lake Pontchartrain	New Orleans	LA	2257	-	-	213
CBJB	Choctawhatchee Bay	Joe's Bayou	FL	292	2323	5158	150
PCLO	Panama City	Little Oyster Bar	FL	326	-	-	501
PCMP	Panama City	Municipal Pier	FL	2392	-	**33**	**2689**
SAWB	St. Andrews Bay	Watson Bayou	FL	1833	-	3301	2335
APDB	Apalachicola Bay	Dry Bar	FL	121	52	197	210
APCP	Apalachicola Bay	Cat Point Bar	FL	1700	149	16	174

Metals

In this report we focus our discussion on mercury, nickel, and vanadium, which are the most prevalent crude oil-related metal contaminants (Nadkarni, 1991; Osuji and Achugasim, 2010). Iron is also commonly associated with oil, but due to its commonly high background concentration in bivalves (unpublished Mussel Watch data, http://egisws02.nos.noaa.gov/nsandt/index.html#), iron was not used in this report as an indicator of oil of possible oil related contamination. All metal values are reported as total metal concentrations (i.e. not individual metal speciation).

Key Findings from Site Specific Oyster Tissue Vanadium Analysis

- At most of the monitoring sites, vanadium concentrations in post-landfall oyster samples were at comparable levels or lower than pre-landfall values (Figure 5). At some sites however, post-landfall vanadium levels were elevated relative to pre-spill values. Vanadium concentrations in post-landfall oyster samples were higher than pre-spill values at sites in Galveston Bay (GBSC, GBTD), Terrebonne Bay (TBLB), Mississippi Sound (MSBB, MSPB), Mobile Bay (MBCP), Pensacola Bay (PBPH, PBIB) and Apalachicola Bay (APCP).

- Aside from the sites in Galveston Bay and Apalachicola Bay, all of the aforementioned high concentration sites were located in the potentially oiled coastal area where oil and tar balls have been observed. Further study is recommended to explain this pattern.

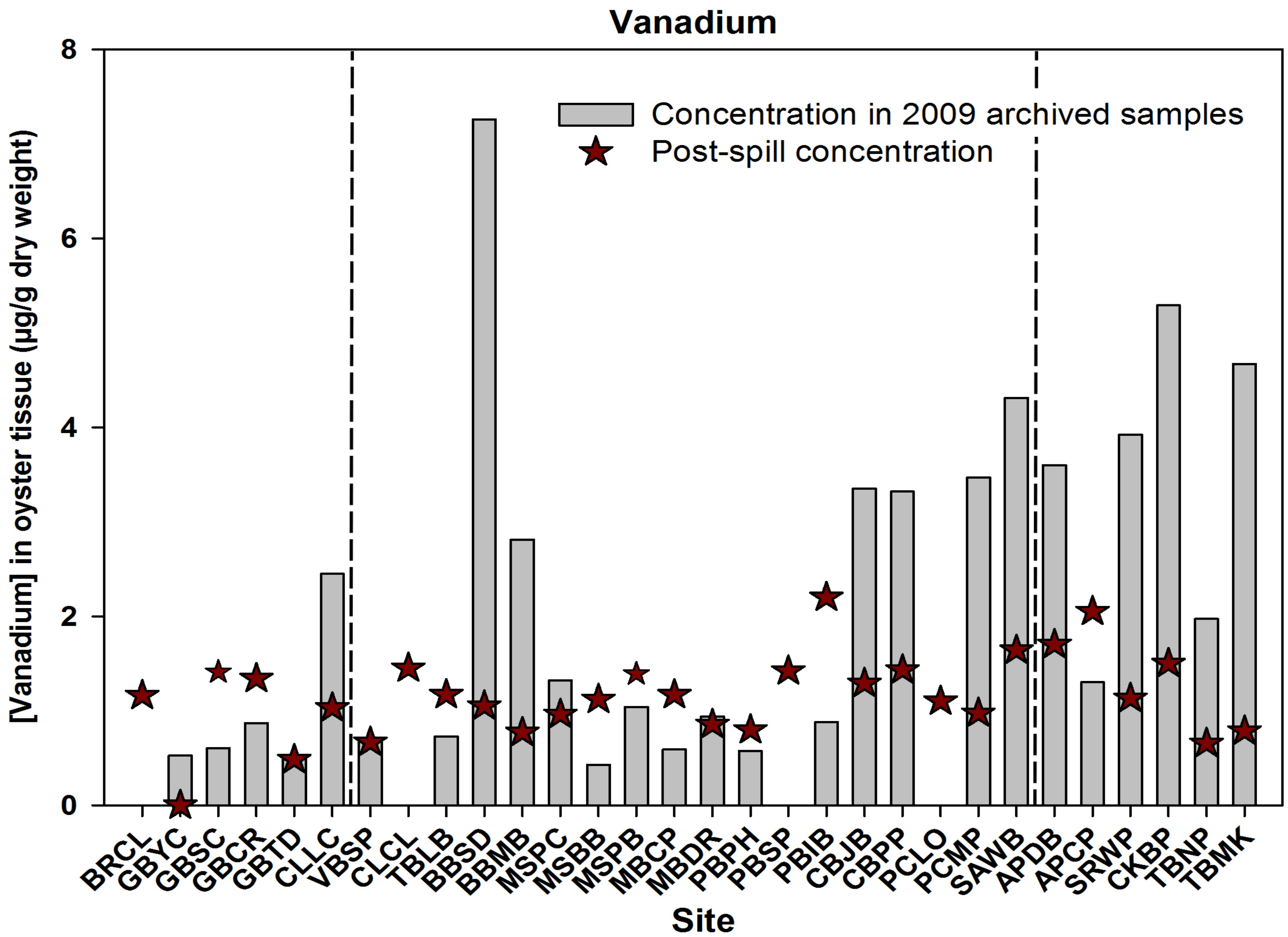


Figure 5. Comparison of pre- and post-landfall concentrations of vanadium in oyster tissue. Bar chart depicts pre-landfall vanadium concentrations in oyster tissue collected in 2008/2009. Overlaid stars represent site-specific vanadium concentrations in oysters collected in Nov 2010.

Key Findings from Site Specific Oyster Tissue Nickel Analysis

- At most of the monitoring sites, post-landfall nickel values in oyster were within historic concentration ranges. At some sites however, post-landfall nickel levels were elevated relatively to pre-spill values.

- As illustrated in Figure 6, nickel concentrations in post-landfall oyster tissue were higher than pre-spill values at sites in Caillou Lake (CLCL), Terrebonne Bay (TBLB), Mississippi Sound (MSPC), Mobile Bay (MBCP, MBDR), Pensacola Bay (PBIB), Choctawhatchee Bay (CBPP), Panama City coastal area (PCLO, PCMP) and Apalachicola Bay (APDB).

- Many of these high concentration sites were located in the potentially oiled coastal area where oil and tar balls have been observed (Figure 1). Further study is warranted to explain these observations.

- The U.S. FDA has established the maximum permissible action level of 80 $ug.g^{-1}$ nickel wet weight in shellfish for seafood safety (FDA, 1993). Maximum nickel concentrations in post-landfall oyster tissue were well below the FDA action level and we estimate nickel concentrations did not cause seafood safety concerns.

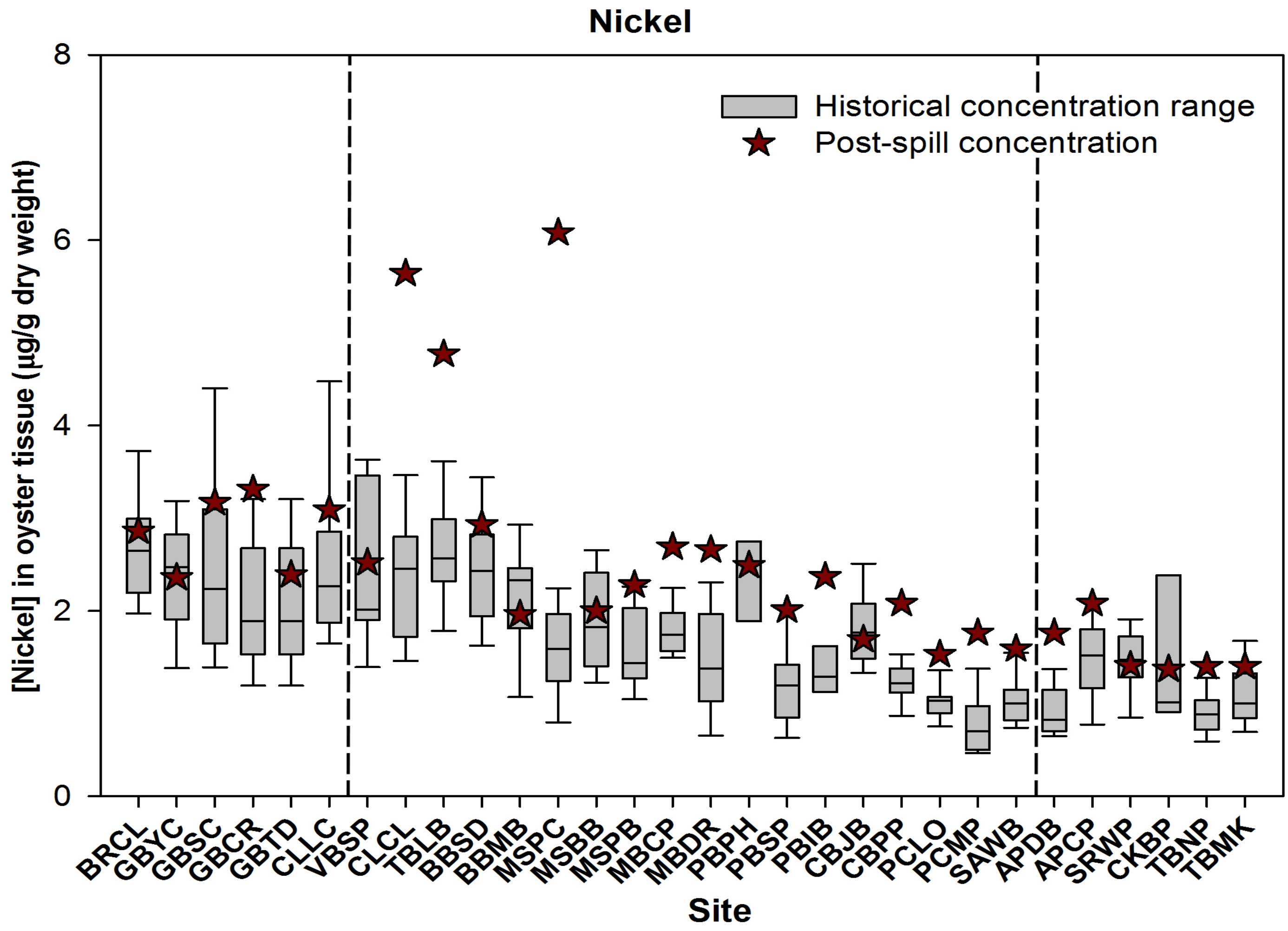


Figure 6. Site-specific comparisons of post-landfall nickel concentrations (star) in oyster tissue to long-term (1986 – 2009) concentration ranges (boxplot). The upper and lower limits of the boxplots represent the 25th and 75th percentiles respectively, the whiskers represent the 5th and 95th percentiles, and the line in the middle of the box is the median.

Key Findings from Site Specific Oyster Tissue Mercury Analysis

- All post-landfall mercury concentrations in oyster tissue were within or below long-term site specific ranges (Figure 7).

- The U.S. FDA has established the maximum permissible action level of 1.0 $\mu g.g^{-1}$ mercury wet weight in shellfish for seafood safety (FDA, 1993). Our results indicated that mercury concentrations in oyster tissue were below the FDA action level and are not a current food safety concern at these sites.

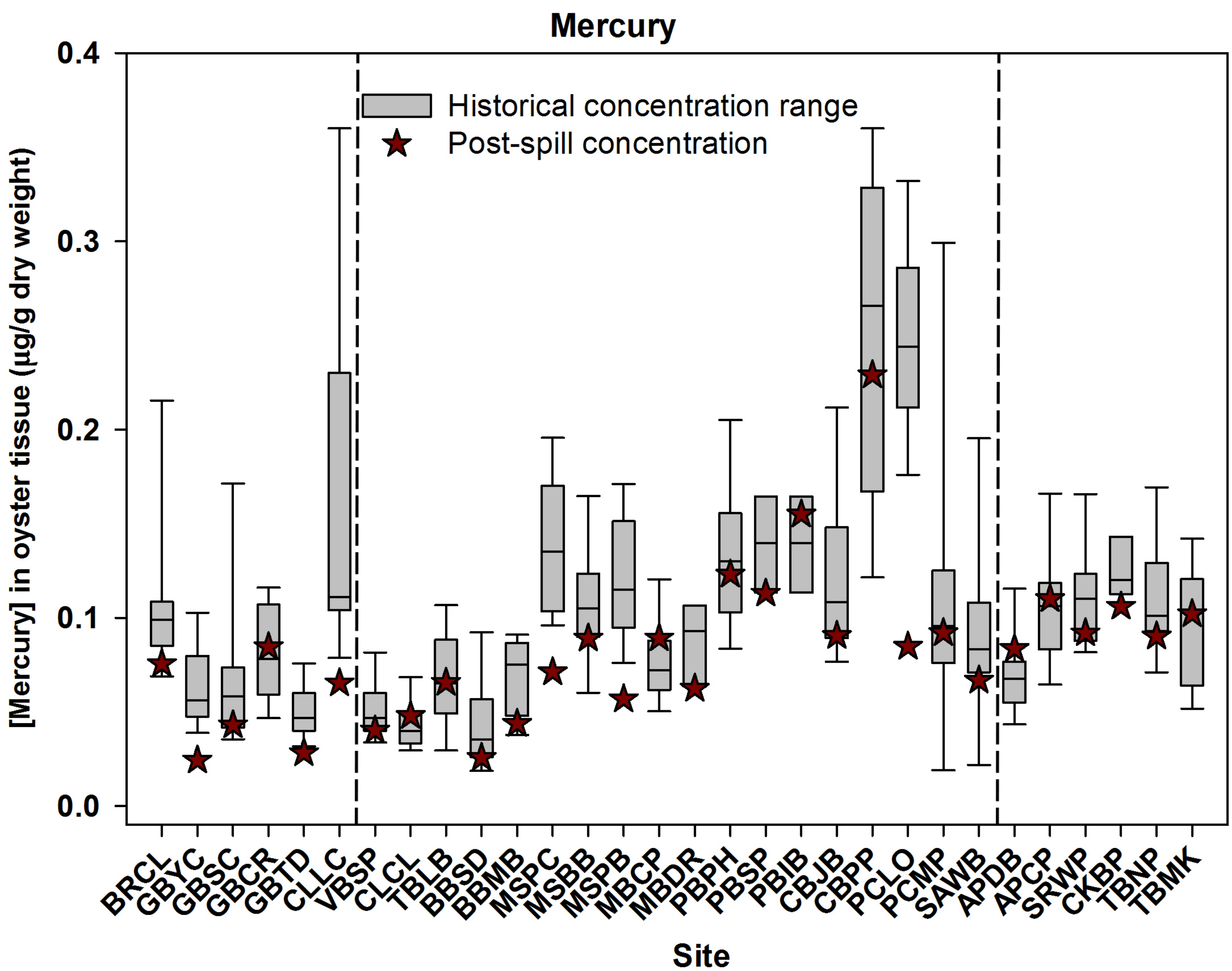


Figure 7. Site-specific comparisons of post-landfall mercury concentrations (star) in oyster tissue to long-term (1986 - 2009) concentration ranges (boxplot). The upper and lower limits of the boxplots represent the 25th and 75th percentiles respectively, the whiskers represent the 5th and 95th percentiles, and the line in the middle of the box is the median.

Overall Summary

- Comparison of the overall magnitude of total PAHs in sediments and oysters to historic Mussel Watch data indicates that there is no conclusive evidence of an increase in Gulf-wide PAH sediment contamination from the Deepwater Horizon oil spill.

- Site-specific total PAH data for sediment and oysters indicate the possibility of oiling at a few sites. Further sampling at these sites is needed to determine the origin, extent, and impact of contamination.

- In general, post-spill concentrations of oil-related trace metals were found to be within the site-specific long-term ranges based on Mussel Watch monitoring data. However, in a few instances post-landfall concentrations exceeded long-term maximum concentrations. These sites deserve further attention to more specifically examine these patterns.

- Concentrations of major oil-related metals such as vanadium, nickel and mercury were also mainly within their respective site-specific long-term range. However, at some sites located within oiled coastal areas post-spill concentrations were relatively higher than historical maximum concentrations, again suggesting the need for further study.

- Relative to the FDA's maximum permissible action levels for shellfish consumption (FDA, 1993), post-landfall concentrations and long-term levels of all potentially toxic metals that NS&T monitored as a part of the Deepwater Horizon impact assessment were below associated action levels.

Acknowledgments

Robert Warner, W. Edward Johnson, Cliff Cosgrove (NOAA) assisted with field work. Juan Ramirez (TDI-Brooks) provided laboratory Quality Assurance support for PAH analysis across different programs. Greg Piniak provided helpful comments of a scientific and editorial nature on this document. Logistical field support was provided by Jim Culter of Mote Marine Laboratory, Meagan LaPeyre of Louisiana State University, Dale Stevens of NOAA NMFS Southeast Fisheries Science Center Pascagoula Lab, and through a contract with Quaternary Resource Investigations, LLC.

References

(ATSDR) Agency for Toxic Substances and Disease Registry. 1995. Toxicological profile for polycyclic aromatic hydrocarbons (PAHs) (update). Atlanta, GA: US Department of Health and Human Services.

ATSDR. 2009. Case Studies in Environmental Medicine (CSEM). Toxicity of Polycyclic Aromatic Hydrocarbons (PAHs). Available at: http://www.atsdr.cdc.gov/csem/pah/index.html

Choi, K.S., Lewis, D.H., Powell, E.N., and Ray, S.M. 1993. Quantitative measurement of reproductive output in the American oyster, *Crassostrea virginica* (Gmelin) using an enzyme-linked immunosorbent assay (ELISA). Aquacult. Fish. Management, 24:299-322.

Eisler, R. 1987. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85(1.11).

U.S. Food and Drug Administration (FDA). 1993. Guidance Document for Arsenic (or Cadmium/Chromium/Lead/Nickel) in shellfish. Department of Health and Human Services, Public Health Service, Food and Drug Administration, Center for Food Safety and Applied Nutrition, Office of Seafood, Washington, DC.

Johnson, W.E., Kimbrough, K.L., Lauenstein, G.G., and Christensen, J.D. 2008. Chemical contamination assessment of Gulf of Mexico oysters in response to hurricanes Katrina and Rita. Environmental Monitoring and Assessment 150(1-4):211-25.

Kim, Y., Ashton-Alcox, K.A., and Powell, E.N. 2006. Histological Techniques for Marine Bivalve Molluscs: Update. Silver Spring, MD. NOAA Technical Memorandum NOS NCCOS, 27. 76 pp.

Kimbrough, K.L., Xommey, S., Apeti, D.A., and Lauenstein, G.G. 2010. Chemical contamination assessment of the Hudson-Raritan Estuary as a result of the attacks on the World Trade Center: analysis of trace elements. Marine Pollution Bulletin, 60(12) 2289-1196.

Kimbrough, K.L., Johnson, W.E., Lauenstein, G.G., Christensen, J.D., and Apeti, D.A. 2008. An Assessment of Two Decades of Contaminant Monitoring in the Nation's Coastal Zone. Silver Spring, MD. NOAA Technical Memorandum, NOS NCCOS 74. 105 pp.

Kimbrough, K.L., and Lauenstein, G.G. 2006. Major and Trace Element Analytical Methods of the National Status and Trends Program: 2000-2006. Silver Spring, MD. NOAA Technical Memorandum NOS NCCOS 29.

Kimbrough, K.L., Lauenstein, G.G., and Johnson, W.E. (Eds.). 2007. Organic Contaminant Analytical Methods of the National Status and Trends Program: Update 2000-2006. NOAA Technical Memorandum NOS NCCOS 30.

Lauenstein, G.G., and Kimbrough, K.L. 2007. Chemical contamination of the Hudson-Raritan Estuary as a result of the attack on the World trade Center: analysis of polycyclic aromatic hydrocarbon and polychlorinated biphenyls in mussels and sediment. Marine Pollution Bulletin, 54(3) 284-294.

Lauenstein, G.G., and Cantillo, A.Y. 1998. Sampling and Analytical Methods of the National Status and Trends Program Mussel Watch Project: 1993-1996 Update. NOAA Technical Memorandum NOS NCCOS 130. Silver Spring, Maryland.

McDonald, S.J., Frank, D.S., Ramirez, J.A., Wang, B., and Brooks, J.M. 2006. Ancillary Methods of the National Status and Trends Program: 2000-2006. Update. Silver Spring, MD. NOAA Technical Memorandum, NOS NCCOS 28. 17 pp.

Mix, M.C., Hemingway, S.J., and Schaffer, R.L. 1982. Benzo(a)pyrene concentrations in somatic and gonad tissues of bay mussels, *Mytilus edulis*. Bull. Environ. Contam. Toxicol. 28: 46–51.

Nadkarni, R.A. 1991. Moderns Instrumental Methods of Elemental Analysis of Petroleum Products and Lubricants. "STP 1109". American Society for Testing and Materials (ASTM) TP691. A68 1991. Philadelphia, PA.

National Commission on BP Deewater Horizon Oil Spill and Offshore Drilling. 2011. Deep Water: The Gulf Oil Disaster and the Future of Offshore Drilling. Report to the President. http://www.oilspillcommission.gov/sites/default/files/documents/DEEPWATER_ReporttothePresident_FINAL.pdf.

OSAT 2010. Summary report for sub-sea and sub-surface oil and dispersant detection: sampling and monitoring. Operational Science Advisory Team, Unified Area Command, Deepwater Horizon MC252, 17 December 2010.

Osuji, L.C., and Achugasim, O. 2010. Trace metals and volatile aromatic hydrocarbon content of Ukeliede_I oil spillage site Niger Delta, Nigeria. Journal of Applied Science of Environment and Management, 14(2) 17-20.

Roesijadi, G. 1996. Environmental factors: response to metals. In: Kennedy, V.S., Newell, R.I.E., and Eble, A.F. (Eds). Eastern oyster *Crassostrea virginica*. Maryland Sea Grant College. College park, Maryland, (pp. 515-537).