A comparison of Shoreline Cleanup Assessment Technique (SCAT) visual observations of oiling and measured soil and sediment chemical concentrations following the 2010 Deepwater Horizon accident.

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Abstract

This study examines the Deepwater Horizon SCAT results in comparison to measured chemical concentrations in shoreline sediments. Surface and subsurface oiling levels were grouped into oiling categories from Very Light to Heavy as per SCAT protocol. Discrete sediment and soil sample locations from the shoreline and immediate nearshore from 27 separate NRDA studies were separated into the SCAT oiling category zones. Measurements of chemical constituents associated with petroleum (i.e., PAH, saturated hydrocarbons, petroleum biomarkers) were used to evaluate the concentration and composition of petroleum present in samples. Hydrocarbon source interpretation ("fingerprinting") was used to identify and exclude samples which were conclusively not DWH oil. Analysis of the chemical distributions in shoreline sediments shows that the oil character varied greatly in time and space, often over very small distances. Average PAH and alkane concentration data tend to agree with the SCAT designations, however, the concentration of petroleum chemicals in any individual sample could not be predicted by SCAT category alone. The results suggest limited predictive ability in specific locations; however, they are useful to estimate the average conditions within the landscape setting in the northern Gulf of Mexico and in the design of injury studies.

Introduction

The Deepwater Horizon (DWH) accident released up to 4.9 million barrels of oil into the Gulf of Mexico between 20 April and July 2010 (OSC Report 2011) and is unprecedented in size in U.S. Coastal waters. Despite on-water efforts to collect, disperse and burn the oil at sea to help minimize coastal habitat exposure, a portion of the spilled oil reached the shorelines across the northern Gulf of Mexico. Surface water transport from the spill site to the shoreline involved three or more weeks for floating oil to reach the shoreline, providing increased weathering time prior to landfall compared to many oil spill incidents which likely affected the nature and degree of shoreline exposure.

The Shoreline Cleanup Assessment Technique (SCAT) is an internationally recognized component of spill response (ASTM 2009) and part of procedures adopted by the National Oceanic and Atmospheric Administration (NOAA), Environment Canada, the U.S. Coast Guard (USCG), the Environmental Protection Agency (USEPA), and numerous Area Contingency Plans worldwide. SCAT data are collected to plan response activities and evaluate changes in oiling levels over time. Stakeholders and scientists from the responsible party, federal and state governments determine appropriate techniques and cleanup endpoints for the affected shorelines by consensus using a systematic and scientifically based survey approach staffed by experts in oil spill science and coastal processes. SCAT data are most useful to evaluate the initial magnitude of oiling and changes in oiling levels over time in order to appropriately assign the best available treatment techniques with the greatest Net Environmental Benefit (NEB). Secondarily, these data are important to the Natural Resource Damage Assessment (NRDA) process that utilizes response and post-spill study data to estimate exposure to marine life and potential service losses resulting from exposure to oil. Services losses are converted to restoration of the affected coastal landscape community, commensurate with losses in each region of the northern Gulf of Mexico. One method of associating service loss with the greater landscape is to draw inferences from SCAT data.

During the incident response, over 22,000 kilometers of shoreline were observed for oil by aircraft and nearly 7,100 kilometers were ground-surveyed by the SCAT process. The data collection effort identified 1,780 kilometers that experienced various levels of oiling and 1,250 kilometers that required some measure of cleaning. The SCAT database contains over 75,000 individual records of shoreline oil observations with GPS locations of oil, description of oil cover and the character of the oil (i.e., fresh, weathered) and is the best available record of oil shoreline exposure associated with the response. In addition, the SCAT process recorded oil observations in over 400,000 excavated pits/holes in the nearshore subtidal zone and provide the best record of observable oil exposure in the shoreline subtidal zone. The SCAT survey process is described in greater detail for this incident by Michel et al. (2013).

SCAT data offer evidence of exposure and do not provide information directly related to environmental injury or the chemical fate and effects of the oil. Subtidal and intertidal sediments are an important pathway through which oil could affect biological resources and habitats. Chronic exposure to oiled sediments has been correlated to reduced feeding and growth, reproductive effects, and histopathological changes in benthic organisms (Hoffmann et al. 2002). The DWH accident was unprecedented in scientific scrutiny with a number of studies meant to quantify the shoreline exposure to hydrocarbons. Concurrently with the SCAT program, 15,000 soil and sediment samples in 27 different NRDA studies were collected for chemical screening and/or chemical analytical analysis for petroleum hydrocarbon concentrations and forensic source allocation evaluation. The SCAT and chemical analytical data used in combination may provide a basis for understanding oil fate and effects in post-oil assessment studies. Simple techniques for drawing inferences based on analytical results applied to broad observations can be developed to portray the scale of potential adverse effects, human health and ecological risks, and to assist in additional study planning and long term monitoring. This paper examines the SCAT data for oil distribution on the northern Gulf of Mexico shorelines in comparison with the cumulative record of chemical analytical data from the response and post-spill studies conducted with the natural resource trustees. The study combines and compares several years of shoreline observations and chemical analytical data to examine broad trends in exposure and suggests possible biological injury assessment approaches that could be complimented by the data. This study does not draw any conclusions regarding potential associated impacts to biological resources from the varying SCAT oil categories and chemical concentrations.

SCAT Data

The SCAT process involves segmenting the shoreline into discrete segments surveyed by trained observers from multiagency and Responsible Party Teams (Figure 1) who systematically record detailed information regarding oiling conditions, including the length and width of oiled bands, percent oil within bands, oil character (e.g., fresh, tar, residue), oil thickness, oil penetration depth into sand, soils, and sediment. Oil observed is classified into five main categories of Heavy, Moderate, Light, Very light, or Tar Ball (‘trace’) oiling, using a standardized categorization system in the database that considers the width of the oil band on the shoreline, the distribution of oil in that band, and the average thickness of the oil (Figure 2, Table 1).

SCAT surveys are often repeated multiple times (i.e., up to 30 or more times in some segments) to judge progress in meeting cleanup endpoints. The SCAT surveys provide the most comprehensive estimate of initial oil exposure and decrease over time on northern Gulf of Mexico shorelines. Exposure is an important aspect of injury determination in the NRDA process.

Figure 1. SCAT teams surveying the shoreline on foot and by boat.

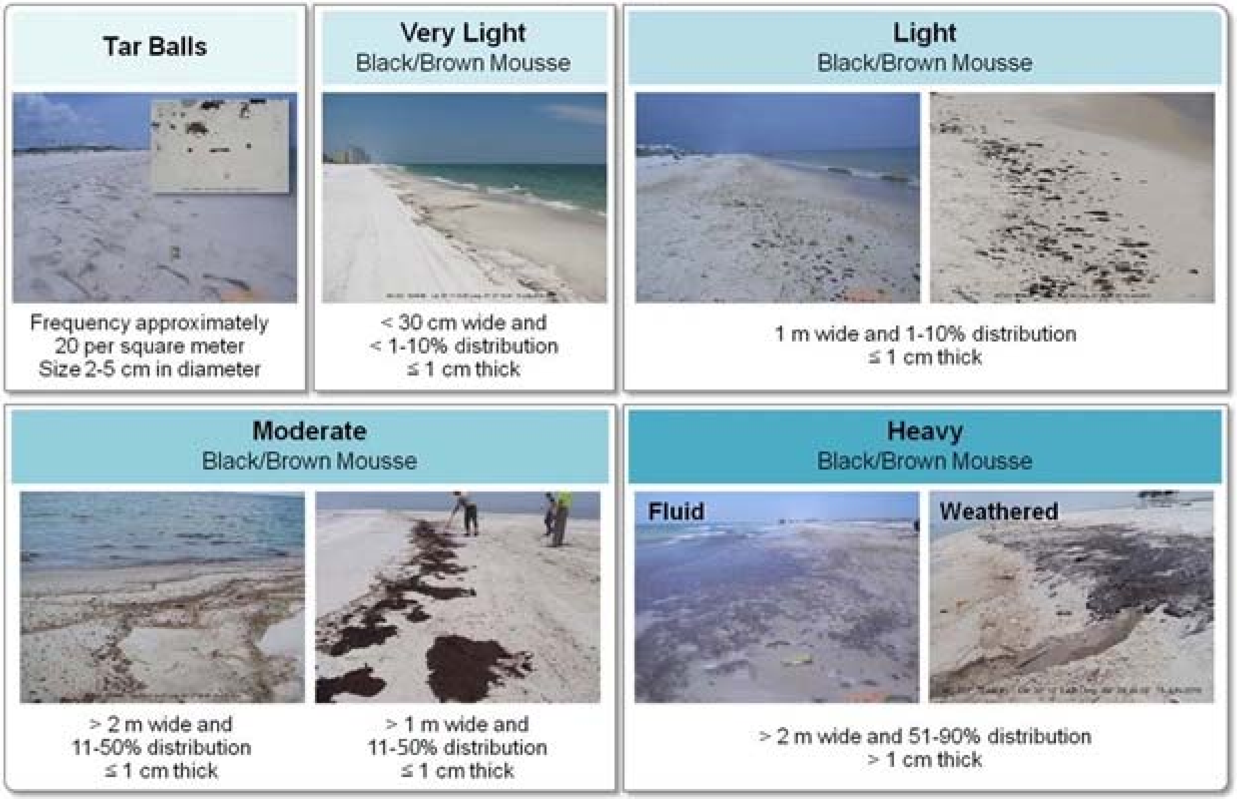

Figure 2. Representative photographs of shoreline oiling categories.

Table 1. Oiling category matrix.

Oil Thickness	**Oil Band** (Width of Oiled Area)		**Oil Distribution**				
			91-100%	**51-90%**	**11-50%**	**1-10%**	**<1%**
Thick Oil >1.0 cm	Wide	>6ft	Heavy	Heavy	Heavy	Moderate	Light
	Medium	3 to 6 ft	Heavy	Heavy	Heavy	Moderate	Light
	Narrow	1 to 3 ft	Heavy	Heavy	Moderate	Light	Light
	V.Narrow	<1 ft	Moderate	Moderate	Light	Light	Light
Cover 0.1-1.0 cm	Wide	>6ft	Heavy	Heavy	Heavy	Moderate	Light
	Medium	3 to 6 ft	Heavy	Heavy	Heavy	Moderate	Light
	Narrow	1 to 3 ft	Heavy	Heavy	Moderate	Light	Light
	V.Narrow	<1 ft	Moderate	Moderate	Light	Light	Light
Coat 0.01-0.1cm	Wide	>6 ft	Moderate	Moderate	Moderate	Light	V. Light
	Medium	3 to 6 ft	Moderate	Moderate	Moderate	Light	V. Light
	Narrow	1 to 3 ft	Moderate	Moderate	Light	V. Light	V. Light
	V.Narrow	<1 ft	Light	Light	V. Light	V. Light	V. Light
Stain <0.01	Wide	>6ft	Light	Light	Light	V.Light	V.Light
	Medium	3 to 6 ft	Light	Light	Light	V.Light	V.Light
	Narrow	1 to 3 ft	Light	Light	V.Light	V.Light	V.Light
	V.Narrow	<1 ft	V.Light	V.Light	V.Light	V.Light	V.Light
Film/ Sheen		n/a	Sheen	Sheen	Sheen	Sheen	Sheen

Sediment Chemistry

Chemical data were obtained for over 15,000 discrete sediment and soil samples taken from shoreline and immediate nearshore (i.e., narrow subtidal areas within wading depths) between 2010 and 2012. Approximately 4000 of these samples were analyzed for constituents associated with petroleum (i.e. total petroleum hydrocarbon (TPAH), alkanes and hydrocarbon biomarkers). Methods of analytical oil detection during the Deepwater Horizon Response are described in White et al. (2016). Results from chemical investigations were used as an independent line of evidence of oil impact in SCAT–defined exposure areas. Only studies that randomly sampled sediment were included in the investigation. Studies that involved targeting and sampling of beached oil itself (e.g. picking up tarballs) were not considered as representative of the average shoreline oiling distribution. The chemical concentrations measured in combination with the locations of samples not measured based on screening criteria provides more specific information regarding the nature of oiling. The chemical investigations were used as an independent line of evidence of oil impact in SCAT–defined exposure areas.

Results

Analysis of the chemical distributions of TPAH in shoreline sediments shows that the oil distributions varied greatly in time and space, often over very small scales. Patchy distribution of oil is evidenced by the distribution of sample TPAH concentrations in each SCAT oil group (Figure 3). Overall, the trends in TPAH and alkane concentrations align with the SCAT designations, which address degree of oiling and hence degree of chemical and physical exposure. However, the concentration of petroleum chemicals in any individual sample could not be predicted by SCAT category alone (Figure 3). The predictive ability is complicated by screening measures undertaken during analysis, which exclude samples without obvious oil in the initial GC-FID chromatogram. The expected result of the screening was to overestimate the prevalence of high TPAH samples (and therefore potential toxicity) in all areas. Adding the screening values as NOO to in their relative proportion of NOO analytical samples in each group indicates lower distribution of elevated TPAHs in all areas (Figure 4). The average overall percent cover (distribution) of maximum oil in Heavily oiled sand beach areas was calculated from the SCAT database is 25% oil cover across the average beach width. An estimate of 60% or more random samples in Heavily oiled shoreline areas containing little or no oil residue is consistent with with SCAT observations of total surface oil distribution (Figure 4).

"Background" oiling is a chronic condition along the Gulf of Mexico. Oil residues in the form of tar have been documented on the Gulf of Mexico shorelines without an acute input source (such as an oil spill) Henry et al. 1993). Many of the chemical components of oil can arise from sources not related to petroleum such as burned wood. Erosion of coastal areas has been reported as a likely dominant background PAH source to the Gulf of Mexico (Mitra and Bianchi, 2003). Other sources of PAH in the shoreline areas of the northern GoM include other operations, pipelines, tank farms, and non-petrogenic sources such as urban runoff. In addition to the anthropogenic sources identified, hydrocarbon seeps in the Gulf of Mexico provide a natural source of petroleum to these shorelines (Geyer and Sweet 1973).

Analysis of the chemistry of shoreline sediment and soil samples and the application of chemical fingerprinting methods help to distinguish areas oiled as a result of the DWH accident from areas with hydrocarbons and hydrocarbon components from other sources. An understanding of the background concentrations of chemicals of interest (e.g., PAH) is required to appropriately determine the impact of any MC252 oil. Hydrocarbon source interpretation ("fingerprinting") was used to identify and exclude samples which were conclusively not MC252 oil. Unified Command collected samples of oil for oil source interpretation under a number of sampling programs to aid in response planning and decision making. These samples included oil, tar balls, mousse, oiled vegetation, sheen, and sediment and generally came from areas suspected to be affected by MC252 oil.

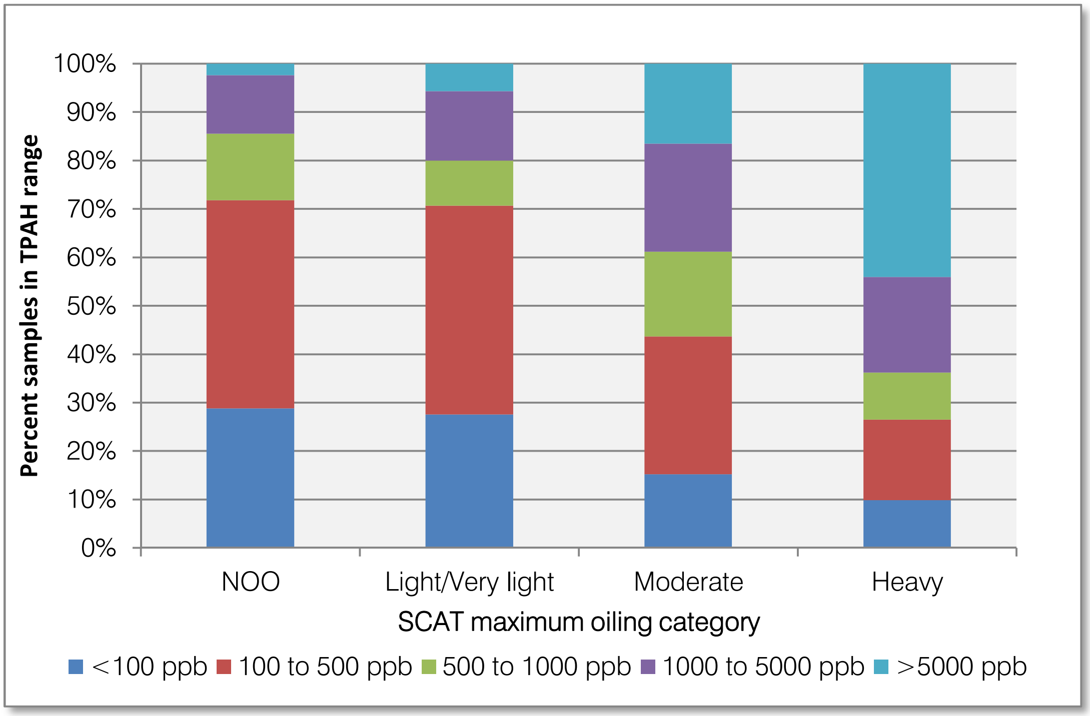

Figure 3. Distribution of TPAH concentrations in surface sediment samples based on maximum SCAT oiling category. Background (non-MC252) TPAH ranged over an order of magnitude based on habitat type. No samples were excluded based on source interpretations. Sample sizes: NOO = 1411, VL/L=645, M=393, H=1209.

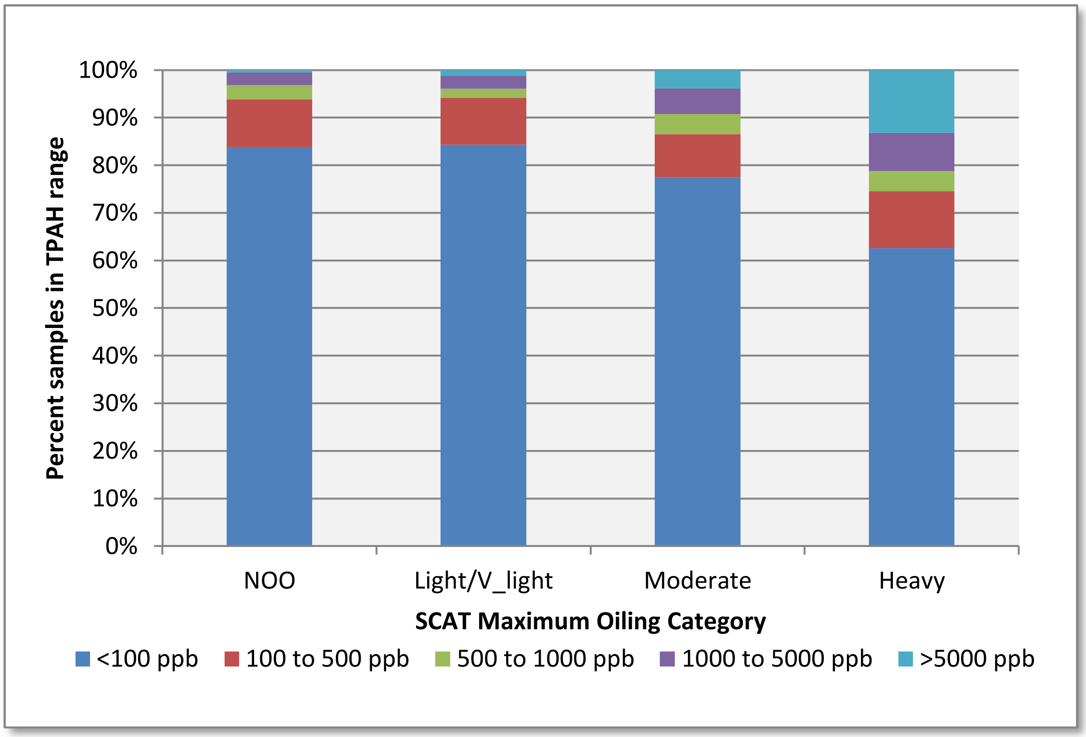

Figure 4.Distribution of TPAH concentrations in surface sediment samples based on maximum SCAT oiling category including sasmples pre-screened as NOO. Sample sizes: NOO=6,551, VL/L=3,054, M=1,430, H=2,918.

Results of source interpretation showed many of samples did not have chemical signatures consistent with MC252 oil (Table 2). This is consistent with literature and background studies conducted prior to the spill showing numerous petroleum inputs in the northern GoM (Henry et al. 1993). Sediment samples with no source interpretation were assumed to be MC252 if they contained a PAH signature consistent with a petroleum-based source for the purpose of our assessment, although 36% of samples in the forensic assessment were confirmed to be derived of other sources (Table 1), we are not aware of the randomness of the investigation.

Table 2. Results of Oil Source Interpretations from tarball and beached oil samples collected from 2010 to 2013.

		Oil Source Interpretation Category[1]				
Spatial Zone	**Year**	**No crude present**	**Not MC-252 crude oil**	**Indeterminate source**	**Weathered MC-252 crude oil**	**Grand Total**
AL	2010		1		14	15
	2011		16	1	17	34
FL	2010		1	2	5	8
	2011		14		10	24
	2012			3	1	4
LA	2010	6	42	9	92	149
	2011		23	2	13	38
	2012		1	1	14	16
MS	2010				4	4
	2011		14		9	23
	2012		4	2	13	19
	2013				2	2
TX	2010	1	12	1	4	18
Grand Total		7	128	21	198	354

Average TPAH concentrations in the surface sediment samples were fit to first order degradation equations for each SCAT oiling level. The analysis was restricted to Louisiana sediment samples only, as that was the state with sufficient sample numbers to produce reliable trends. Results showed that an apparent first order degradation model fit well for Heavy, Moderate and Light oiling categories (R^2>0.83), indicating that oil degradation was occurring steadily and predictably in these environments (Figure 5). Based on the TPAH concentration data, Heavy and Moderate SCAT locations are expected to trend toward background

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concentrations by 2016, while the light SCAT segments (both beach and marsh) should have returned to background concentrations by 2012. The NOO category was not fit to the model, as no temporal concentration trend was seen, and degradation-based concentration changes would not be expected for samples unaffected by the oil. The decline in chemical concentrations of petroleum hydrocarbons from 2010 to 2012 compares well with the decline in higher oiling categories from SCAT (Figure 6). These data provide an independent line of evidence of recovery through oil removal activities and decrease in availability to biota.

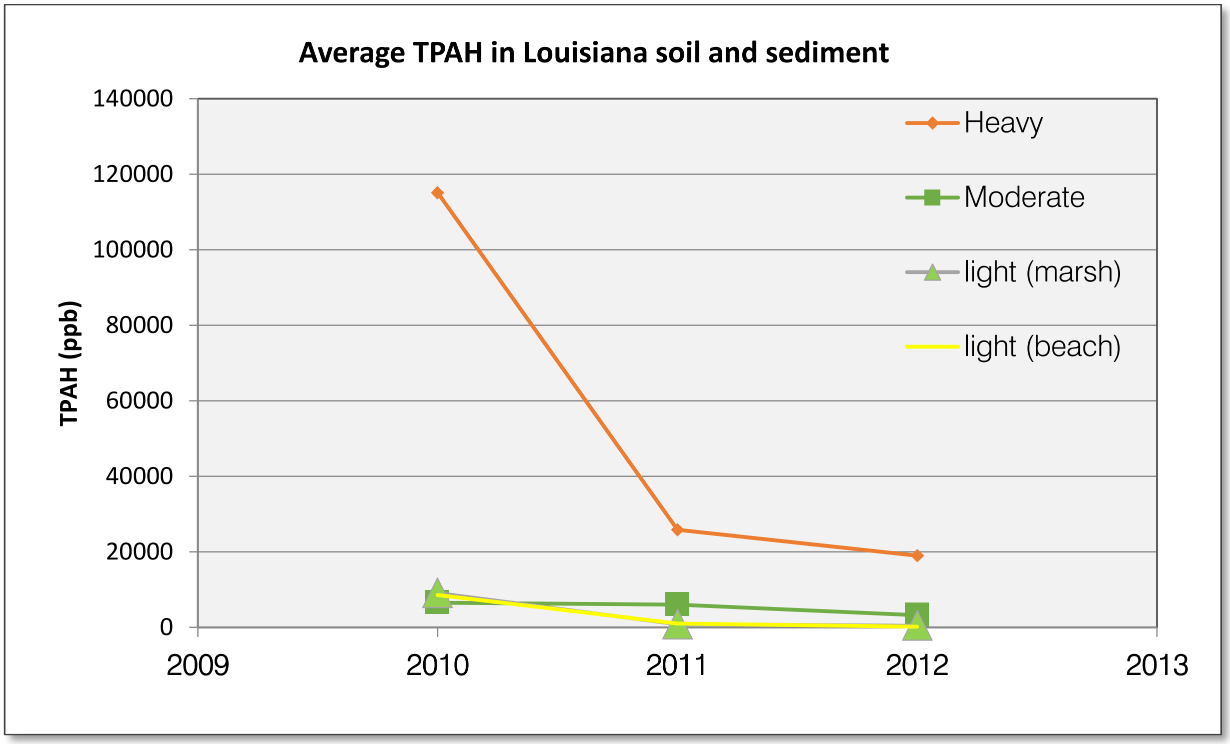

Figure 5. Average TPAH over time in LA soils and sediments.

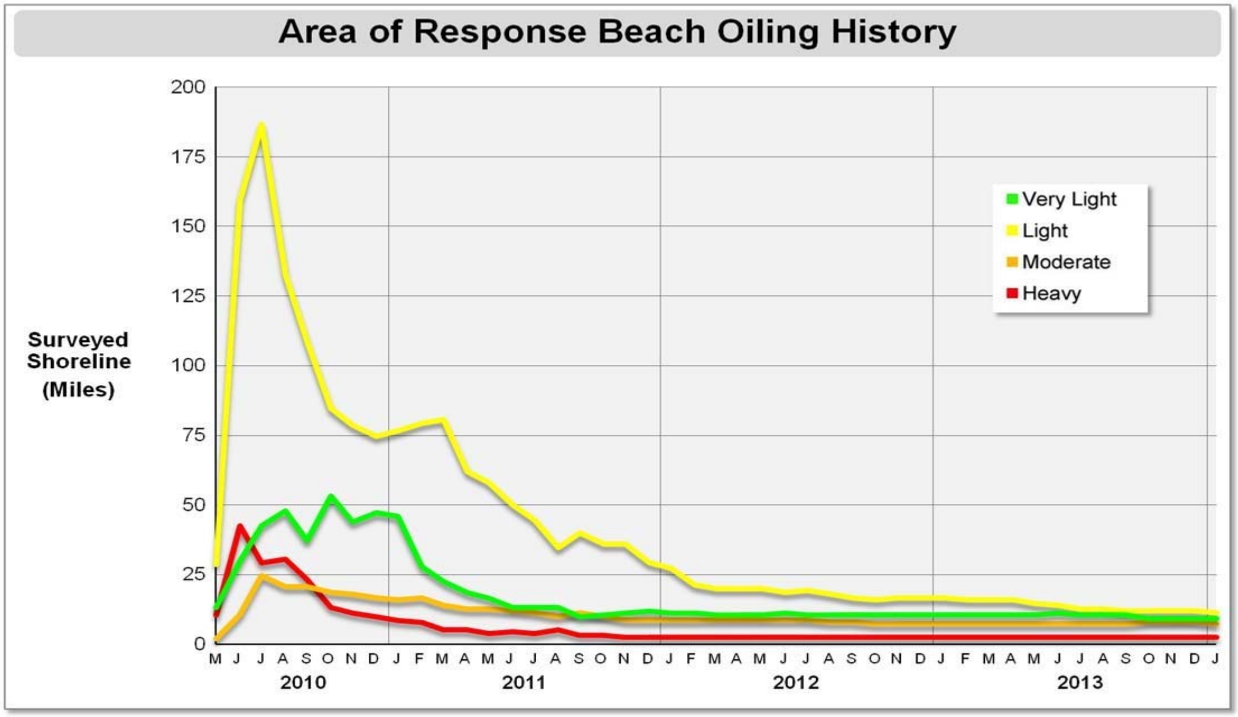

Figure 6. Decline in max oiling condition over time on Gulf of Mexico sand beaches (SCAT 2014).

Discussion

The data suggest limited predictive ability of exposure in specific locations; however, they are useful to estimate the average conditions within the landscape setting in the northern Gulf of Mexico. The large sample sizes and good correlation of analytical and SCAT information allow estimates of average oil cover and chemical concentrations associated with the oil cover. This information together offers the ability to estimate potential exposure of biota in the larger setting. The oil cover, band width and linear distances on maximum SCAT oil observations were totaled to estimate the initial observed oil coverage by major habitat category (Table 3). The estimates do not reflect subsequent oil movement in tides and storms and provide a relative comparison and likely underestimate of cumulative exposure. Linear oiling data from the SCAT database for Louisiana indicate approximately 15% of sand beach shorelines received Heavy oiling and less than 3% of surveyed marsh shorelines were Heavily oiled (Table 4). There are other methods that may be used to refine exposure estimates based on tide data and oil movement and they should all be considered for validation of inferences.

Table: 3. Estimated initial maximum oil exposure (acres) based on average percent distribution, oil band widths and linear distances within segments.

HABITAT	H	M	L	VL	Total
Sand Shoreline	**4564.4**	**962.3**	**5529.3**	**936.2**	**11992.2**
Back Bay	*501.9*	*79.6*	*398.5*	*121.1*	*1101.0*
Barrier Island	*1919.9*	*432.4*	*2482.6*	*372.0*	*5206.9*
Mainland (Non-Residential/Non-Amenity/SMA)	*1197.9*	*312.9*	*1329.8*	*192.6*	*3033.2*
Mainland (Residential/Amenity)	*944.7*	*137.5*	*1318.3*	*250.6*	*2651.1*
Herbaceous Marsh/*Spartina*	**860.0**	**757.0**	**714.0**	**121.0**	**2452.0**
Barrier Island Herbaceous	**162.0**	**734.0**	**129.0**	**8.0**	**1033.0**
***Phragmites* Marsh**	**349.0**	**344.0**	**127.0**	**11.0**	**831.0**
Mangrove Marsh	**109.0**	**34.0**	**68.0**	**3.0**	**214.0**
Hard Surfaces	**3.0**	**1.0**	**7.0**	**14.0**	**25.0**
Total	**6047.4**	**2832.3**	**6574.3**	**1093.2**	**16547.2**

Table 4. Estimated SCAT observed linear oiling in Louisiana (miles).

Louisiana Shoreline Habitat	**Total Surveyed**	**Heavy**	**Moderate**	**Light**	**Very Light**	**Trace (<1%)**	**No Oil Observed**
	Miles	Miles	Miles	Miles	Miles	Miles	Miles
Beach	601.4	89.1	46.7	104.9	48.9	39.7	272.1
Marsh	4607.5	137.6	158.9	193.1	213.5	32.2	3872.2
Other	84.1	1.5	3.4	1.5	4.9	0.0	72.8
Totals	**5293.0**	**228.2**	**209.0**	**299.5**	**267.3**	**71.9**	**4217.2**

Oil exposure determination investigations applied to broad settings as part of NRDA typically use the SCAT data that are readily available as part of the incident response to help scale the application of injury assumptions and/or studies. The exposure data can be translated to service loss estimates using several methods including specific injury studies on receptor organisms or assumptions from chronic toxicity approaches and sentinel organism. Injury probability based on exposure evidence and published research can help managers designing studies to determine sample sizes necessary to detect minor effects that may be expected in lower oiling categories or determine whether there is a reasonable expectation of finding a definitive result for the required effort.

The exposure and chemical data from the DWH incident are not comparable for all spills. There is limited published literature comparing SCAT designations and chemical analytical results following oil spills although the data likely exist within numerous NRDA assessments. A comparison of average soil PAH in SCAT categories from a nearshore bunker oil spill in British Columbia, Canada (Challenger and Sergy 2007) indicate substantial differences in average oil concentrations when compared to the DWH SCAT categories (Figure 7). The differences are due to factors such as the initial PAH content of the oils, the degradation of the DWH oil from an offshore source, shoreline geomorphology, tides, currents and the magnitude and distribution of the oil as it washed ashore. The data may be used to supplement an understanding of the magnitude and landscaping setting associated with the many biological injury studies that have occurred since the incident or to draw general inferences in similar settings and situations.

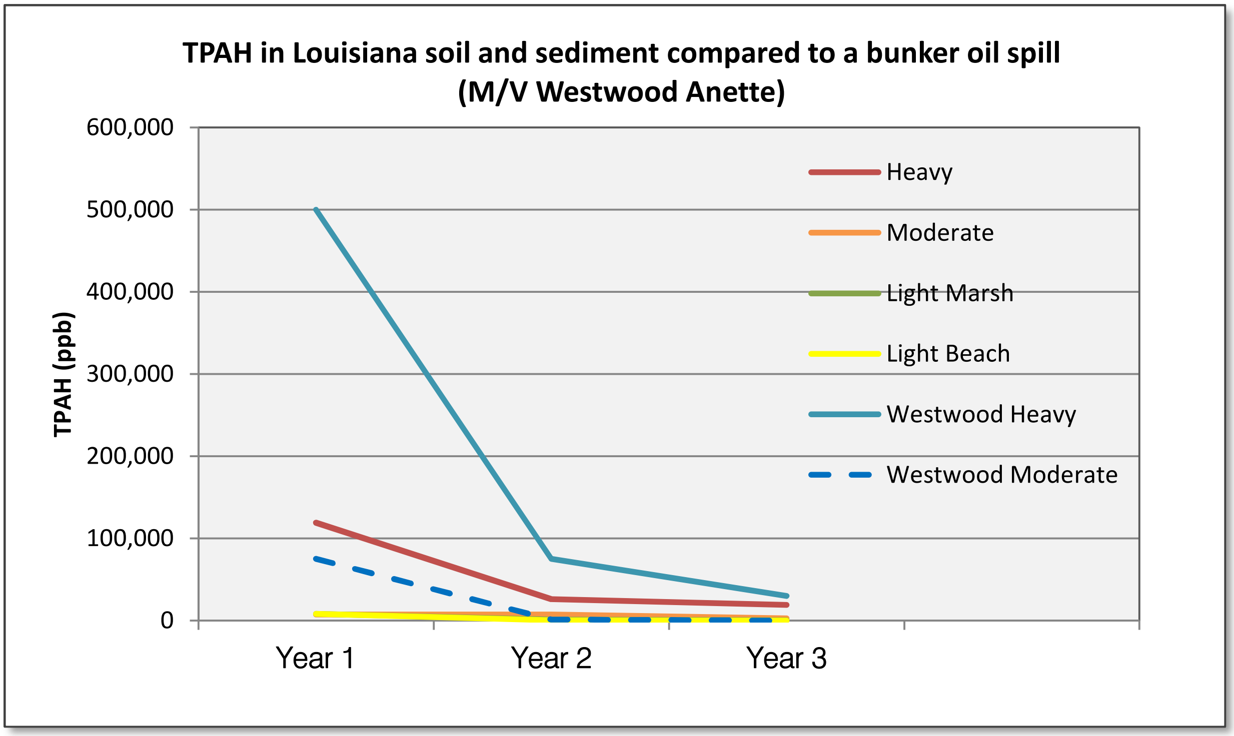

Figure 7. Decline in average TPAH in DWH sediments compared to SCAT oil category for a nearshore bunker oil spill in a temperate climate (M/V Westwood Annette, British Columbia, Canada 2007).

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