The 2015 Refugio Beach Oil Spill: Field Assessment of Subtidal Exposure

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INTRODUCTION

On May 19, 2015, an underground pipeline (Line 901), owned and operated by Plains All American Pipeline, L.P., and Plains Pipeline, L.P., sustained a release of crude oil near Refugio State Beach in Santa Barbara County, California. Oil from the pipeline flowed down a culvert and entered the Pacific Ocean in the nearshore environment. *Phyllospadix spp*. (surfgrass), *Zostera marina* (eelgrass) and *Macrocystis pyrifera* (giant kelp) beds were observed to be oiled. Additionally, dead fish and invertebrates associated with these habitat types were observed on beaches in the spill affected area. The purpose of this study was to document exposure within the nearshore and offshore subtidal habitats adjacent to Refugio State Beach. Vegetation, invertebrate and sediment samples were collected from or near the seafloor and analyzed for polycyclic aromatic hydrocarbons (PAHs). A series of biomarkers was also measured to assist in fingerprinting the source of the oil, differentiating between Line 901 oil and oil from nearby seeps. This report summarizes the field collection methods and general results of the fingerprinting analysis.

METHODS

Field Sampling Procedures

On May 31, 2015, thirteen days after the spill, three sampling locations were selected near Refugio State Beach (Figure 1): K1, a kelp bed at a depth of approximately 15 ft (4.6 m); E2, an eelgrass bed at a depth of approximately 29-33 ft (10 m); and P1, a *Phyllospadix* or surfgrass bed at a depth of approximately 8-15 ft (2.4-4.6 m). The dive boat anchored at each location while a team of two divers swam to the bottom to collect vegetation and invertebrates. The divers collected specimens along a 30 meter transect from the boat to the shore, and the specimens were selected randomly. The invertebrate and algal/vegetation specimens were collected for tissue analysis and were reflective of the various habitats that were considered oiled (Table 1). These habitats included kelp beds, surfgrass beds, eelgrass beds and rocky reefs along with their associated invertebrates. The sampled material was placed in a mesh dive bag for transport to the boat. Grab sediment samples were collected from the top two centimeters of subtidal sediments using glass jars. On the boat, samples were photographed, taxonomically identified, labeled and transferred with gloved hands into a sample container. Vegetation, small invertebrate and sediment samples were collected in 250 ml wide-mouth, pre-cleaned glass jars with Teflon-lined lids. Larger invertebrate samples were wrapped in aluminum foil. Samples were placed in a cooler with ice on the boat and were then transported via FED-EX to Alpha Analytical Laboratory.

Figure 1. *May 31, 2015 sampling locations near Refugio State Beach*.

Chemical Analysis

Analytical chemistry methods are detailed in Stout (2016). Briefly, aliquots of some subtidal tissues were rinsed (exterior surfaces) with dichloromethane (DCM), and the rinsate was analyzed separately as an "oil". Tissues, rinsate and sediment extracts were analyzed for PAHs by GC/MS-SIM (USEPA Method 8270 mod). Results for these 50 individual PAHs and alkylated homologue groups were summed to estimate total PAHs ($TPAH_{50}$): naphthalene; naphthalenes, C1; naphthalenes, C2; naphthalenes, C3; naphthalenes, C4; acenaphthylene; acenaphthene; fluorene; fluorenes, C1; fluorenes, C2; fluorenes, C3; phenanthrene; anthracene; phenanthrene/anthracene, C1; phenanthrene/anthracene, C2; phenanthrene/anthracene, C3; phenanthrene/anthracene, C4; pyrene; benzo(b)fluorene; fluoranthene; fluoranthene/pyrenes, C1 -; fluoranthene/pyrenes, C2; fluoranthene/pyrenes, C3; fluoranthene/pyrenes, C4; benz[a]anthracene; chrysene; chrysenes, C1; chrysenes, C2; chrysenes, C3; chrysenes, C4; benzo(a)pyrene; benzo(e)pyrene; benzo(b)fluoranthene; benzo(k)fluoranthene; benzo(a)fluoranthene; benzo(g,h,i)perylene; indeno(1,2,3-c,d)pyrene; dibenz(a,h)anthracene; dibenzothiopene; dibenzothiophenes, C1; dibenzothiophenes, C2; dibenzothiophenes, C3; dibenzothiophenes, C4; biphenyl; dibenzofuran; naphthobenzothiophene; naphthobenzothiophene, C1; naphthobenzothiophene, C2; naphthobenzothiophene, C3; and naphthobenzothiophene, C4. When calculating $TPAH_{50}$, non-detects were assumed to be zero. Tissue results are reported on a wet weight basis and sediment on a dry weight basis. Fingerprinting methods are detailed in Stout (2016).

RESULTS and DISCUSSION

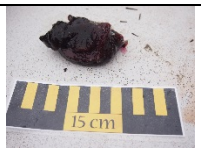
Field Observations and Sample Collection

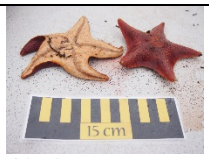
At the K1 kelp bed site, oil sheen and globules were observed on the water surface (Figure 2). Eight algal samples of six different species and eight invertebrate samples of at least seven species were collected (Table 1). Initially, a known eelgrass bed was planned for sampling. However, a derrick barge was anchored directly over the bed (Figure 3), prohibiting access. Accordingly, a second eelgrass bed (E2) was selected where one eelgrass, two invertebrate and three sediment samples were collected (Table 1). At the P1 surfgrass site, seven invertebrate samples of at least six species, two surfgrass samples and one giant kelp sample were collected (Table 1).

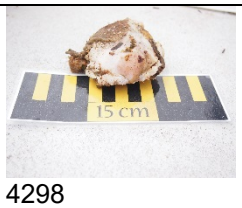
Figure 2. *Surface oil sheen observed at the K1 site on May 31, 2015.*

Figure 3. *The DB San Diego anchored over an eelgrass bed*.

Table 1. Vegetation, invertebrate and sediment samples collected at the kelp bed (K1), eelgrass bed (E2) and surfgrass (P1) sites on May 31, 2015

Sample ID	Species	Photo
K1 – Kelp Bed Site		
RSBITED1001	*Panulirus interruptus* (California spiny lobster)	 4269
RSBVTED1002	*Pterygophera californica* (pom-pom kelp)	 4271
RSBVTED1003	*Egregia menziesii* (feather boa kelp)	 4272
RSBVTED1004	*Sargassum sp.*	 4273
RSBITED1005	*Strongylocentrotus franciscanus* (red sea urchin)	 4274
RSBITED1006	*Styleia montereyensis* (tunicates)	 4275
RSBITED1007	*Aplysia vaccaria* (sea hare)	 4276

Sample ID	Species	Photo
RSBITED1008	*Norrisia norrisii* (Norris top snail)	 4277
RSBITED1009	*Patiria miniata* (bat star)	 4278
RSBITED1010	Multiple snails (cowrie, wavy top snail, whelk snail)	 4279
RSBVTED1011	*Macrocystis pyrifera* (giant kelp)	 4280
RSBITED1012	*Styleia montereyensis* (tunicates)	 4282
RSBVTED1037	*Cystoseira sp.* (chain bladder kelp gas bladder)	 4283
RSBVTED1038	*Cystoseira sp.* (chain bladder kelp blade)	 4284
RSBVTED1039	*Sargassum sp*	 4285

Sample ID	Species	Photo
RSBVTED1040	*Eisenia arborea* (southern sea palm)	 4286
E2- Eelgrass Bed Site		
RSBITED1041	*Diopatra ornata* (ornate tube worm)	 4287
RSBVTED1042	*Zostera pacifica* (eelgrass)	 4288
RSBITED1043	*Kelletia kelletii* (Kellet's whelk)	 4289
RSBSED1007 RSBSED1008 RSBSED1009	Sediment from eelgrass bed – 29ft deep	No photos taken
P1 – Surfgrass Site		
RSBITED1044	*Panulirus interruptus* (CA spiny lobster)	 4296
RSBITED1045	*Norrisia norrisii* (Norris top snail)	 4297
RSBITED1046	*Crassadoma gigantea* (rock scallop)	 4298

Sample ID	Species	Photo
RSBITED1047	*Aplysia vaccaria* (sea hare)	 4299
RSBVTED1048	*Phyllospadix sp.* (surfgrass)	 4300
RSBVTED1049	*Phyllospadix sp.* (surfgrass)	 4301
RSBVTED1050	*Macrocystis pyrifera* (giant kelp)	 4302
RSBITED1051	*Strongylocentrotus franciscanus* (red sea urchin)	 4303
RSBITED1052	*Strongylocentrotus franciscanus* (red sea urchin)	 4303
RSBITED1053	Multiple snails (cowaries)	 4304

Tissue $TPAH_{50}$ and Fingerprinting Results

PAHs were detected in vegetation samples at all three locations and possible, probable and definitive matches to Line 901 oil were determined via fingerprinting (Table 2; Stout, 2016). There was good agreement between the forensic classification results obtained on the whole (unrinsed) tissue samples and on the rinsates, indicating that external oiling occurred (Stout, 2016). Tissues were classified as indeterminate, often due to low

detectable hydrocarbons. $TPAH_{50}$ concentrations in vegetation samples were highest in the surfgrass samples.

Table 2. *Vegetation $TPAH_{50}$ and Fingerprinting Results*

Site	Sample ID	Vegetation Species	$TPAH_{50}$ (ug/kg ww)	Fingerprint (Stout 2016)	Rinsate Fingerprint
K1	RSBVTED1039	*Sargassum sp*	64	**Possible A**	**Possible A**
K1	RSBVTED1038	*Cystoseira sp.* Chain bladder kelp blade	32	**Match**	**Probable Match**
K1	RSBVTED1040	*Eisenia arborea* (southern sea palm)	26	**Possible A**	Indeterminate
K1	RSBVTED1003	*Egregia menziesii* (feather boa kelp)	20	Non-Match	Non-Match
K1	RSBVTED1011	*Macrocystis pyrifera* (giant kelp)	16	Indeterminate	Indeterminate
K1	RSBVTED1002	*Pterygophera californica* (pom-pom kelp)	4	Indeterminate	Indeterminate
K1	RSBVTED1037	*Cystoseira sp.* Chain bladder kelp	NA	NA	
K1	RSBVTED1004	*Sargassum sp.*	NA	NA	
E2	RSBVTED1042	*Zostera pacifica* (eelgrass)	74	**Probable Match**	**Probable Match**
P1	RSBVTED1048	*Phyllospadix sp*. (surfgrass)	181	**Probable Match**	**Match**
P1	RSBVTED1049	*Phyllospadix sp*. (surfgrass)	144	**Match**	**Probable Match**
P1	RSBVTED1050	*Macrocystis pyrifera* (giant kelp)	19	**Probable Match**	Indeterminate

NA = Not Analyzed

PAHs were detected in kelp (K1) and surfgrass (P1), and associated invertebrates, and were possibly or definitively matched to Line 901 oil (Table 3). Invertebrate samples from the eelgrass bed site were not analyzed. In the eelgrass bed, sediment concentrations were low and were not matched to Line 901 oil. The highest $TPAH_{50}$ concentration that was matched to Line 901 oil was measured in tunicate tissue at the kelp bed site. Tunicates attach to rocky reefs, are often fouled with algae, and are a filter feeder. $TPAH_{50}$ concentrations were highest in the sea hare, followed by the red sea urchin, and were possibly matched to Line 901 oil. Both of these mobile species feed on algae. Given that vegetation was oiled, diet was a potential oil exposure pathway. Overall, these data provide evidence for exposure of subtidal vegetation and invertebrates to Line 901 oil.

Table 3. Invertebrate and Sediment $TPAH_{50}$ and Fingerprinting Results Tissue PAH Concentrations

Site	Sample ID	Invertebrate Species and Sediment	$TPAH_{50}$ (ug/kg ww)*	Fingerprint (Stout 2016)
K1	RSBITED1012	*Styleia montereyensis* (tunicates)	448	**Match**
K1	RSBITED1005	*Strongylocentrotus franciscanus* (red sea urchin)	401	**Possible B**
K1	RSBITED1006	*Styleia montereyensis* (tunicates)	356	**Match**
K1	RSBITED1010	Multiple snails (cowrie, wavy top snail, whelk snail)	126	**Match**
K1	RSBITED1007	*Aplysia vaccaria* (sea hare)	93	**Possible B**
K1	RSBITED1001	*Panulirus interruptus* – gill tissue (CA spiny lobster)	47	Indeterminate
K1	RSBITED1009	*Patiria miniata* (bat star)	NA	NA
K1	RSBITED1008	*Norrisia norrisii* (Norris top snail)	NA	NA
E2	RSBSED1007 RSBSED1008 RSBSED1009	Sediment (ug/kg dw)	87 160 147	Non-match
E2	RSBITED1043	*Kelletia kelletii* (Kellet's whelk)	NA	NA
E2	RSBITED1041	*Diopatra ornata* (ornate tube worm)	NA	NA
P1	RSBITED1047	*Aplysia vaccaria* (sea hare)	2657	**Possible B**
P1	RSBITED1052	*Strongylocentrotus franciscanus* (red sea urchin)	525	**Possible B**
P1	RSBITED1051	*Strongylocentrotus franciscanus* (red sea urchin)	451	**Possible B**
P1	RSBITED1053	Multiple snails (cowaries)	130	**Match**
P1	RSBITED1044	*Panulirus interruptus* (CA spiny lobster)	NA	Rinsate Indeterminate
P1	RSBITED1045	*Norrisia norrisii* (Norris top snail)	NA	NA
P1	RSBITED1046	*Crassadoma gigantea* (rock scallop)	NA	NA

* sediment is ug/kg dw; NA = Not Analyzed

REFERENCES

Stout, S.A. 2016. Refugio Beach Oil Spill NRDA Investigation: Trustees Forensic Oil Source Analysis. NewFields Government Services, Rockland, Massachusetts. December 19.