The 2015 Refugio Beach Oil Spill: Polycyclic Aromatic Hydrocarbons in Nearshore Fish and Invertebrate Tissues

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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. As a result, the California Department of Fish and Wildlife (CDFW) implemented a fisheries closure, as recommended by the Office of Health Hazard Assessment (OEHHA). CDFW and OEHHA sampled fish and invertebrates to establish the degree and geographic extent of seafood contamination in the impacted area (OEHHA, 2015). The contaminants of concern for human health were the 8 polycyclic aromatic hydrocarbons that have the potential to cause cancer (cPAHs), reported as benzo(a)pyrene equivalents. The concentrations of benzo(a)pyrene equivalents found in finfish and invertebrate tissues were presented in the seafood consumption risk assessment report prepared by OEHHA (2015). However, in addition to the PAHs of human health concern, the fish and invertebrate tissues were analyzed for several other PAHs found in oil for a total of 45 PAHs (TPAH45).

This report provides a summary of the TPAH45 concentrations measured in the tissues. The natural resource trustees for resources affected by the Refugio Oil Spill (Trustees) utilized this information to further evaluate fish and invertebrate exposure in the spill affected area.

METHODS

Field Sampling Procedures
Nearshore finfish and invertebrates were collected from June 10-19, 2015, approximately 3-4 weeks after the spill, from the three CDFW Commercial Fishing Blocks in the closure area (Figure 1 and Table 1; OEHHA, 2015). Details of the sampling and analysis methods are provided in OEHHA (2015).

Chemical Analysis
Skinless filets from fish and edible portions from invertebrates (e.g., crab, prawn and lobster body meat and sea urchin roe) were composited (Table 1), extracted and analyzed for PAHs, as detailed in OEHHA (2015). The gut contents of the sea cucumbers were rinsed out before tissues were composited. As indicated above, the extracts were analyzed for 45 individual PAHs and alkylated homologue groups. Results for these 45 individual PAHs and alkylated homologue groups were summed to estimate total PAHs (TPAH45): naphthalene (N0); C1-naphthalenes as 1-methylnaphthalene (N1-1) and 2-methylnaphthalene (N1-2); C2-naphthalenes (N2); C3-naphthalenes (N3); C4-naphthalenes (N4); biphenyl (B); acenaphthylene (AY); acenaphthene (AE); fluorene (F0); C1-fluorenes (F1); C2-fluorenes (F2); C3-fluorenes (F3); phenanthrene (P0); anthracene (A0); C1-phenanthrene/anthracene (PA1); C2-

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1 The natural resource trustees for the Refugio Oil Spill include the California Department of Fish and Wildlife, the U.S. Department of Commerce through the National Oceanic and Atmospheric Administration, the U.S. Department of the Interior through the Fish and Wildlife Service, the California Department of Parks and Recreation, the California State Lands Commission, and the Regents of the University of California.
phenanthrene/anthracene (PA2); C3-phenanthrene/anthracene (PA3); C4-phenanthrene/anthracene (PA4); dibenzo thiophene (DBT0); C1-dibenzo thiophenes (DBT1); C2-dibenzo thiophenes (DBT2); C3-dibenzo thiophenes (DBT3); pyrene (P); fluoranthene (FL0); C1-fluoranthene/pyrenes (FP1); C2-fluoranthene/pyrenes (FP2); C3-fluoranthene/pyrenes (FP3); C4-fluoranthene/pyrenes (FP4); benz[a]anthracene (BA0); chrysene (BC0); C1-chrysene (BC1); C2-chrysene (BC2); C3-chrysene (BC3); C4-chrysene (BC4); benzo(b)fluoranthene (BBF); benzo(k)fluoranthene (BJKF); benzo(e)pyrene (BEP); benzo(a)pyrene (BAP); perylene (PER); indeno(1,2,3-c,d)pyrene (ICDP); dibenz(a,h)anthracene (DA); C1-dibenz(a,h)anthracene (DA1); C2-dibenz(a,h)anthracene (DA2); C3-dibenz(a,h)anthracene (DA3); and benzo(g,h,i)perylene (GHI). When calculating TPAH45, non-detects were assumed to be zero. Tissue results are reported on a dry weight basis. Moisture content ranged from 71 to 92 percent.

The Trustees also analyzed barred surfperch skinless filets collected on 23 May 2015 from Gaviota State Beach, Refugio State Beach and Campus Point (near Coal Oil Point) for the same 45 PAHs. Methods and results for this surfperch exposure assessment study are presented in Appendix G-3 of the DARP.

![Figure 1](image-url)  
**Figure 1.** Fishery closure area and sampling areas within the commercial fishing blocks (excerpted from Figure 1 of OEHHA, 2015).
Table 1. Number of fish and invertebrate individuals in composite samples collected from Fishing Blocks 654, 655 and 656 (excerpted from OEHHA, 2015). The 10 m depth column indicates whether a sampling location was inshore (“In”) or further offshore, outside of the 10 m bathymetric line (“Out”), as depicted in Figure 2.

<table>
<thead>
<tr>
<th>Species</th>
<th>10 m Depth</th>
<th>654 – Coal Oil Pt</th>
<th>655 - Refugio</th>
<th>656- Gaviota</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Invertebrates</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CA Spiny Lobster (Panulirus interruptus)</td>
<td>In</td>
<td>3</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Red Sea Urchin (Strongylocentrotus franciscanus)</td>
<td>In</td>
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<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Brown Rock Crab (Cancer attennarius)</td>
<td>In</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Sheep Crab (Loxorhynchus grandis)</td>
<td>In</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Warty Sea Cucumber (Parastichopus parvimensis)</td>
<td>In</td>
<td>9</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Giant Red Cucumber (Apostichopus californicus)</td>
<td>Out</td>
<td>8</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>Ridgeback Prawn (Sicyonia ingentis)</td>
<td>Out</td>
<td>12</td>
<td>11</td>
<td>-</td>
</tr>
<tr>
<td>Yellow Rock Crab (Cancer anthonyi)</td>
<td>Out</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Fish</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barred Surfperch (Amphistichus argenteus)</td>
<td>In</td>
<td>9</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Pacific Mackerel (Scomber japonicas)</td>
<td>In</td>
<td>-</td>
<td>10</td>
<td>9</td>
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<tr>
<td>Grass Rockfish (Sebastes rastrelliger)</td>
<td>In</td>
<td>11</td>
<td>13</td>
<td>7</td>
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<tr>
<td>Kelp Rockfish (Sebastes atroirens)</td>
<td>In</td>
<td>9</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>Black and Yellow Rockfish (Sebastes chrysomelas)</td>
<td>In</td>
<td>-</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>Pacific Sanddab (deeper water) (Citharichthys sordidus)</td>
<td>Out</td>
<td>9</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Pacific Sanddab (shallow water) (Citharichthys sordidus)</td>
<td>Out</td>
<td>-</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Vermillion Rockfish (Sebastes miniatus)</td>
<td>Out</td>
<td>8</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Bocaccio Rockfish (Sebastes paucispinis)</td>
<td>Out</td>
<td>-</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>

- Not sampled

RESULTS and DISCUSSION

Relative Tissue TPAH$_{45}$ Concentrations in Fishing Blocks and Depth Zones

Spatial and depth zone patterns of TPAH$_{45}$ concentrations in composited fish and invertebrate samples were evaluated. Fishing block 655 (labeled “Refugio”) was closest to the oil release point, near Refugio State Beach, while Block 656 (labeled “Gaviota”) was to the west in an area that included Gaviota State Beach and Block 654 (labeled “Coal Oil Point”) was to the east in an area that included Coal Oil Point (Figure 2). There are active natural oil seeps offshore of Coal Oil Point (Lorenson, 2011).
The 10 m bathymetric line (Figure 2) is the approximate offshore extent of kelp forest and rocky reef habitat which provide critical habitat for fish and invertebrates. The Trustees determined that oil would mix throughout the water column to 10 meters depth through wave and tidal action. Accordingly, fish and invertebrates collected within the 10 m bathymetric line were likely to have experienced greater exposure to oil compared to fish and invertebrates collected farther offshore.

![Figure 2](image)

**Figure 2.** Samples collected within the three fishing blocks in relationship to the 10 m bathymetric line. The red star is the approximate location of the oil release point.

The highest TPAH$_{45}$ tissue concentrations were measured in the warty sea cucumber and red sea urchin composite samples near Refugio State Beach (Figure 3). Lower concentrations for these two species were measured in the fishing blocks to the west (Gaviota State Beach) and the east (Coal Oil Point). The giant red sea cucumber, collected outside of the 10 m bathymetric line in Fishing Block 655 (Figure 4), had TPAH$_{45}$ concentrations over ten times lower than the warty sea cucumber collected closer to shore in this block.
Figure 3. Total polycyclic aromatic hydrocarbon concentrations (TPAH₄₅; ng/g dry weight) in invertebrates collected at or within the 10 m bathymetric line in Fishing Blocks 654, 655 and 656.

Figure 4. Total polycyclic aromatic hydrocarbon concentrations (TPAH₄₅; ng/g dry weight) in invertebrates collected outside the 10 meter bathymetric line in Fishing Blocks 654, 655 and 656. ND = not detected.
Figure 5. *Total polycyclic aromatic hydrocarbon concentrations (TPAH_{45}; ng/g dry weight) in fish collected at or within the 10 m bathymetric line in Fishing Blocks 654, 655 and 656.*

Figure 6. *Total polycyclic aromatic hydrocarbon concentrations (TPAH_{45}; ng/g dry weight) in fish collected outside the 10 m bathymetric line in Fishing Blocks 654, 655 and 656. ND = not detected.*
A similar spatial pattern was seen in fish where there were higher TPAH45 concentrations in filets from fish collected within the 10 m bathymetric line (Figure 5), compared to filets from fish collected outside this depth zone (Figure 6). The highest TPAH45 concentrations in fish were measured in mackerel and barred surperch composite samples near Refugio State Beach (Figure 5), relative to the other fishing blocks. Surperch filet concentrations from fish collected at Refugio State Beach approximately 22 days after the spill (TPAH45 = 30 ng/g dry weight), were lower than surperch filet composites from fish collected 4 days after the spill, from the same location (88 ng/g dry weight; Anulacion et al, 2019; see Appendix G-3 for study details). Since the tissue samples collected to evaluate seafood contamination in the impacted area were collected 3-4 weeks after the spill, TPAH45 concentrations likely underestimated fish and invertebrate tissue concentrations that occurred immediately after the spill. Overall, results indicate exposures were higher within the 10 m depth zone and adjacent to the oil spill release site.

**Comparison of Fish and Invertebrate PAH Concentrations**

Fish filet TPAH45 concentrations were generally lower than what were measured in invertebrate edible tissues (Figures 3-6). Fish have been reported to have greater ability to metabolize and eliminate PAHs, compared to invertebrates (Meador et al, 1995). Additionally, fish muscle tends to have lower PAH concentrations than other fish tissues, such as the liver (Meador et al., 1995; Ylitalo et al., 2012). Another factor potentially contributing to the difference is that some fish are more mobile than invertebrates and some may have been able to move away from the oil contaminated area, or may live and feed in habitats with less oil contamination (Graham et al, 2015; Law and Hellou, 1999). For example, the warty sea cucumber is an epibenthic detritivore that feeds on organic detritus and small organisms within the sediment, a potential depositional zone for the spilled oil (Leet et al., 2001). This feeding strategy may have contributed to the higher TPAH45 concentrations in their tissues.

A wider array of PAHs were detected in invertebrate tissues (Figure 7) compared to fish tissues (Figure 8). In invertebrates, naphthalenes, phenanthrenes and dibenzothiophenes contributed the largest percentages to the TPAH45 concentration, which is similar to other invertebrates analyzed following the Line 901 release (Stout, 2016). Elevated levels of naphthalenes and phenanthrenes in invertebrate tissues have been reported following other oil spills (Boehm et al, 2004; Runney et al., 2011). Naphthalenes were the predominant PAHs detected in fish, which is consistent with other studies of fish contamination following oil spills (Incardona et al, 2011; Xia et al, 2012; Murawski et al., 2014).
Figure 7. Percent composition of polycyclic aromatic hydrocarbons (PAHs) in warty sea cucumber, red sea urchin and giant red sea cucumber in the three fishing blocks. See Methods for PAH abbreviations.
Figure 8. Percent composition of polycyclic aromatic hydrocarbons in mackerel, barred surfperch and grass rockfish in the three fishing blocks. See Methods for PAH abbreviations.

REFERENCES


Office of Environmental Health Hazard Assessment. 2015. Risk Assessment of Seafood Consumption Following the Refugio Beach Oil Spill Incident in Santa Barbara County. December. Sacramento, CA.


