Appendix D. Shoreline Exposure and Injury Evaluation Studies

The Shoreline Technical Work Group (TWG) consisted of two subgroups during the early stages of the Refugio Beach Oil Spill Natural Resource Damage Assessment (NRDA): one focused on sandy beach habitat and the other on rocky intertidal habitat. Subsequently, these subgroups merged to become the Shoreline TWG. The TWG identified several goals early on, including documenting the presence of the oil on shorelines, then documenting oil exposure and injury to shoreline organisms on those stretches of oiled shoreline. The injury evaluations proceeded by bifurcating the assessment of injuries attributable to oil exposure and injuries attributable to cleanup operations. Table 1 shows the planning strategy for the Sandy Beach TWG in October 2015. A similar strategy, documenting exposure and effects, was employed to assess rocky intertidal habitat injuries. Data and other information used to prepare this report are found in the Administrative Record for the case at https://www.diver.orr.noaa.gov/web/guest/diver-admin-record/6104.

		Planning - Sandy Beach TWG
	Injury Assessment	
Category	**Assessment Goal**	**Data type**
Contaminant	Oil presence	Photographs of oil
		Tarball samples & Observational Data (field notes, SCAT, etc.)
Exposure	Exposure of beach organisms to oil	Photos of oiled organisms
		Chemistry of tissue; Emerita, Euzonus, Talitrids
		Pore water chemistry on sandy beaches
		Mussel tissue chemistry results; PAHs
		Surf water chemistry results (PAHs)
Effects	1. Effects of oil on organisms	Dead organisms (photos, waypoints, and 'dead box' counts)
		Talitrid population survey data
		Grunion data, reproductive success
		Chemistry of beach invertebrate tissues; Emerita, Euzonus, Talitrids
		Mussel tissue chemistry results
		Bioassay results
	2. Effects of cleanup operations on organisms	Form 214 &/or 204 forms from response and notes documenting cleanup activity
		Wrack removal data
		Cobble and sand removal data
		Wrack survey data
		Talitrid survey data
		Vehicle use on beaches

Table 1. A draft table detailing the planning done for the sandy beach TWG from October 2015.

Presence of Oil

The presence of oil on shoreline was verified in several ways, including documenting it with photographs (Figure 1). These photos were generated from various sources, including Trustee personnel from the US Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA), University of California at Santa

Barbara (UCSB), and California Department of Fish and Wildlife (CDFW), as well as other contractors, partners and the media.

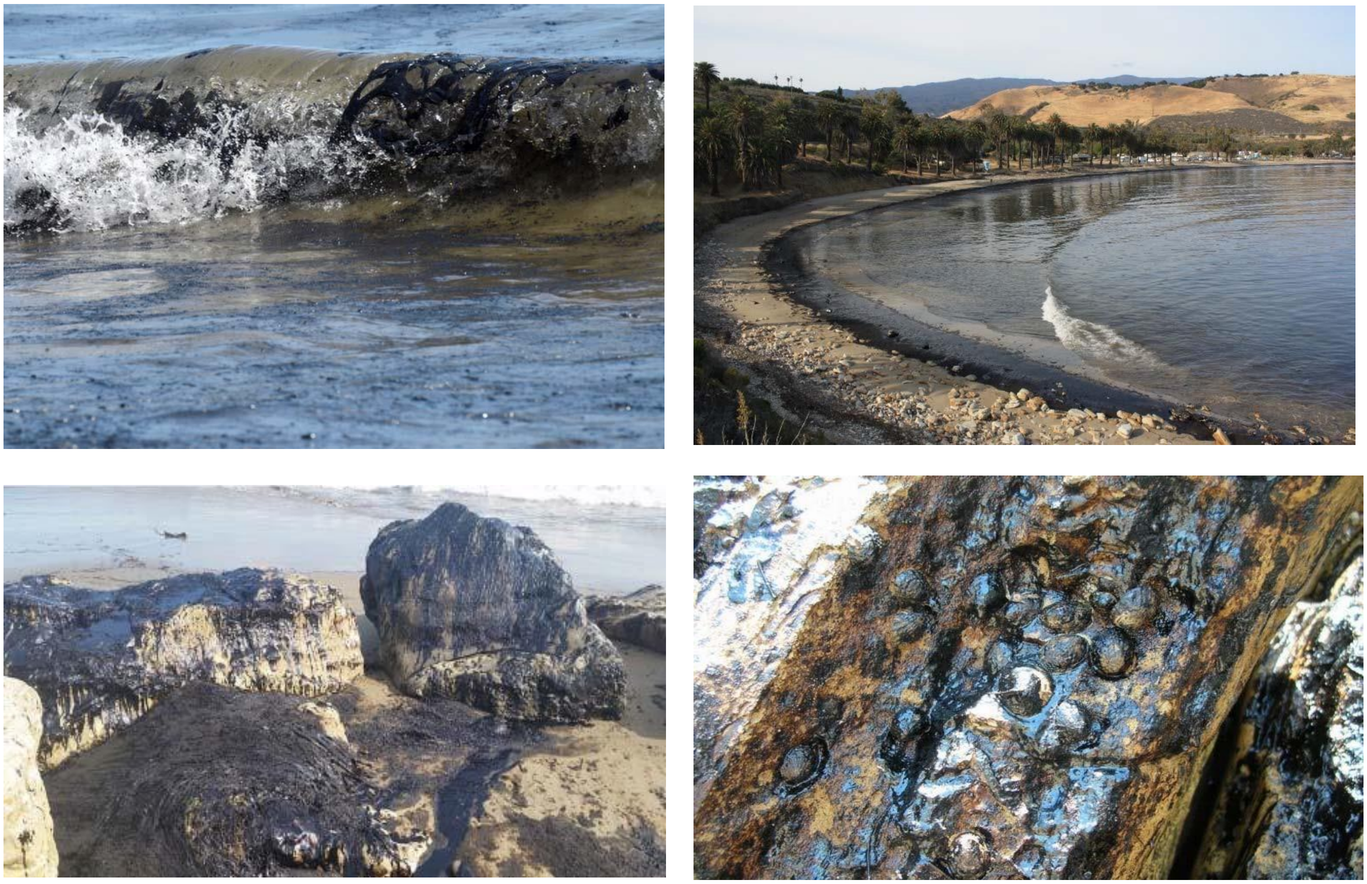

Figure 1. Photographs of Line 901 oil in the surf and on the shoreline, May 2015.

Because oil from natural seeps can be found along the southern California coast, it was important to verify the presence of Line 901 oil at oiled locations. Samples of ‘source oil’ were collected from the source of the spill on May 21, 2015, by the Trustees for forensic purposes. The Trustees also collected field samples of oil at a variety of shoreline locations in Santa Barbara, Ventura, and Los Angeles Counties. The samples were analyzed and then compared to the source oil to confirm the presence of Line 901 oil at the various oiling locations. In addition, the Trustees documented observations of oiling condition and other relevant observations of oiling on the shorelines.

The Trustees also considered observations of shoreline oiling documented by spill response Shoreline Cleanup and Assessment Technique, or SCAT teams, for response and cleanup purposes, i.e., “SCAT data”. Spill trajectory modeling results were also considered in conjunction with field observations and oil chemistry results. For example, the NOAA GNOME (General NOAA Operational Modeling Environment) model generated a trajectory showing the oil moving southeast all the way to Redondo Beach in Los Angeles County in late May 2015 (Appendix A of the Damage Assessment and

Restoration Plan). This was consistent with observations of shoreline oiling and the chemical analysis results for a tarball collected at Manhattan Beach.

Figure 2. Sand crabs fouled and affected by the Line 901 oil on 19 May 2015, at Refugio State Beach.

Exposure to Oil

Exposure to Line 901 oil was documented in several ways, ranging from observations that were recorded in field notes to photographs of oil on or in association with organisms (Figures 1 and 2), as well as a variety of chemical measurements of oil constituents in field samples. Chemical analysis results, including concentrations of polycyclic aromatic hydrocarbons (PAHs), were obtained from both surf water and porewater samples. Porewater is the water that exists in the pore spaces between sand grains. PAHs are known to be a toxic fraction of crude oil that is taken up by organisms. Surf water and porewater come into contact with a wide range of organisms, including three species sampled on sandy beaches: sand crabs (*Emerita analoga*), polychaete worms commonly referred to as Euzonus (*Thoracaphelia spp*.), and talitrids, more commonly known as beach hoppers (*Megalorchestia spp.*).

Multiple tissues types were collected at multiple locations at multiple points in time following the spill and analyzed for PAHs to document the extent of exposure to these toxic components of crude oil (Figure 3). This allowed for both a spatial and a time series data evaluation, providing a better understanding of where PAH uptake was occurring, its magnitude, and how long it persisted. Details on the forensic chemical results for tissues can be accessed in Appendix B of the Damage Assessment and Restoration Plan.

Mussels (*Mytilus spp.*), which attach to rocky substrates, were also sampled and chemically analyzed. The chemistry results confirmed that mussels were exposed to oil-derived PAHs in the surf water. The Trustees obtained hundreds of chemistry results from these different environmental media (e.g., water, sediment, tissues) to document the exposure of shoreline habitats and selected organisms to the chemical components of Line 901 oil (see Appendix B of the Damage Assessment and Restoration Plan).

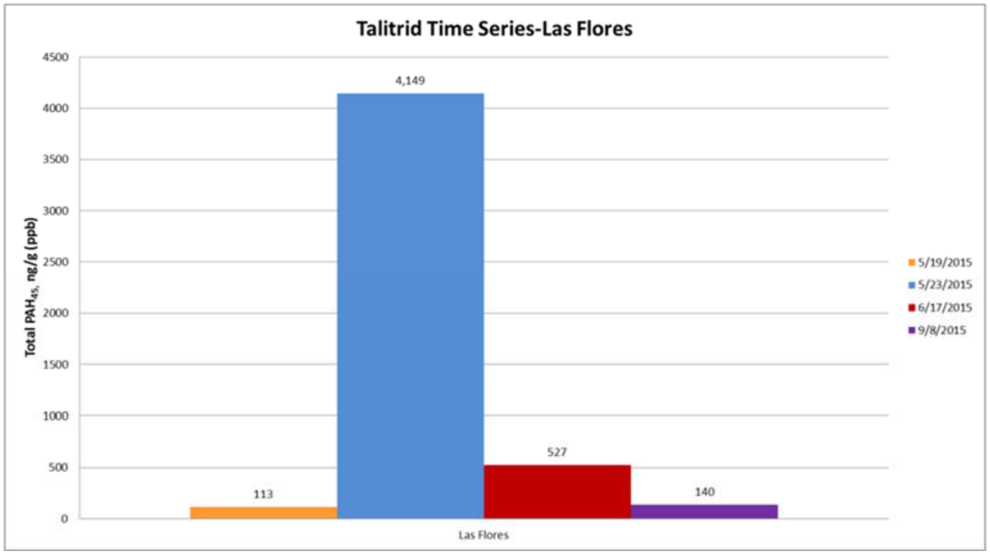

Figure 3. Talitrid tissue chemistry results for one sandy beach location, Las Flores, from a time series in 2015.

Injury

Shoreline injuries were categorized into two primary areas, injuries attributable to exposure to the oil and injuries attributable to the cleanup effort.

Effects of Oil

There was early and obvious evidence of the toxicity of the spilled material to aquatic and terrestrial organisms in the days following the Line 901 rupture and oil spill (Figure 4). Dozens of dead subtidal organisms (multiple species of various life stages) washed up on nearby shorelines in the days following the spill and were observed by NRDA teams and cleanup crews. The organisms were so numerous that response personnel overseeing early-phase cleanup activities and debris removal from Refugio State Beach contacted NRDA staff to discuss how best to capture and document the carcasses being found on the shoreline before they were disposed of along with all the other oily debris being removed by cleanup workers. A system for collecting these carcasses in boxes was quickly arranged. By day two or three of the spill cleanup, cleanup workers began separating the carcasses from other oily materials being removed from the beach and placing them into boxes to be photographed and enumerated by an NRDA team each day. This data set became known as the “dead box” data by the NRDA Trustees. This data provides evidence of injury to the subtidal- and shoreline-associated organisms that had washed up dead or in a moribund condition on nearby shorelines immediately following the spill. A summary of the types and numbers of organisms collected during this effort can be found in Appendix G-1 of the Damage Assessment and Restoration Plan.

Figure 4. A subset of the dead organisms found on 21 May 2015, Refugio State Beach.

The Trustees conducted talitrid population surveys to evaluate the impacts of the oil spill on these important sandy beach organisms. Talitrids are important processors of organic matter, especially kelp, also known as wrack deposits, and are also an important food source for shorebirds foraging on sandy beaches in California. The talitrid population survey results (Dugan, 2018) indicated their abundance, biomass, and age class distribution were affected by shoreline oiling as well as response operations. Talitrids were surveyed using standard methodologies developed by Dr. Jenny Dugan of the University of California at Santa Barbara. Where possible, the results of these surveys were compared to prior or reference conditions from earlier surveys at the same locations to evaluate the impacts of the oil spill on these organisms. In addition to the population surveys, survey teams photographed moribund or dead talitrids found in the oil that was deposited on the shoreline (Figure 5).

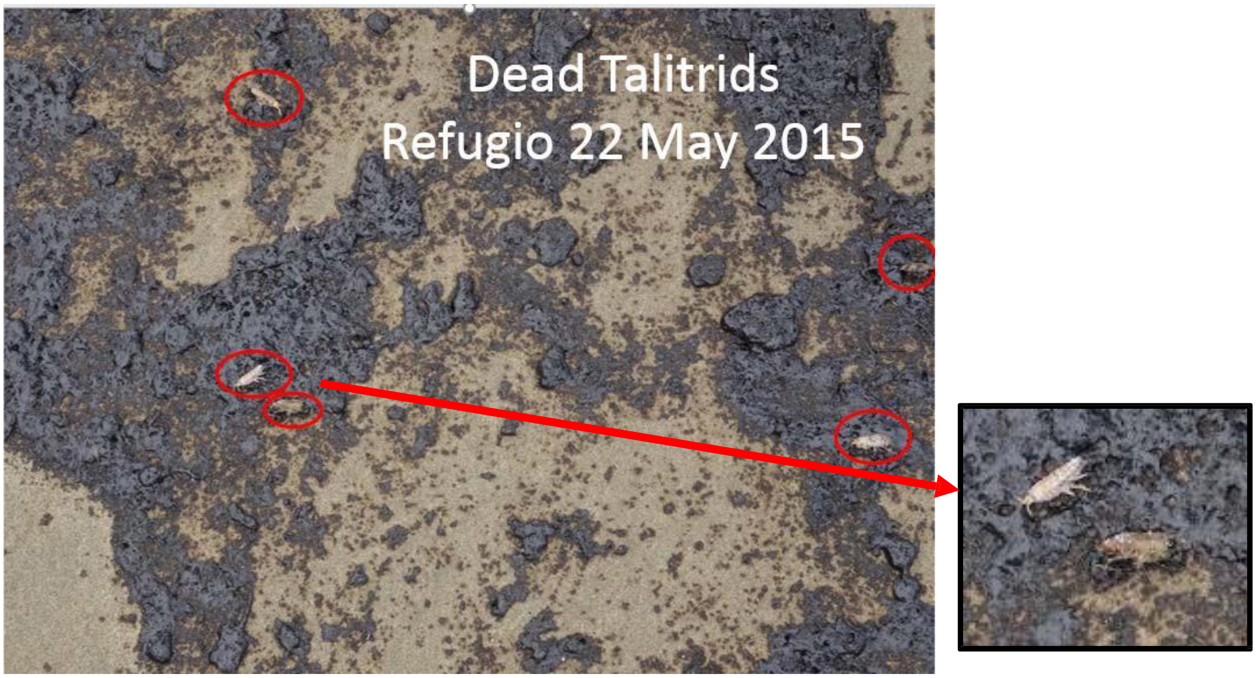

Figure 5. Talitrids found dead in oil deposits on the beach on 22 May 2015, Refugio State Beach.

To evaluate the toxic of effects of the 901 oil, bioassays, also known as toxicity tests, were conducted with the oil collected near the site of the Line 901 pipe rupture. Two common shoreline organisms were tested: the sand crab (*Emerita analoga)*, and the mussel (*Mytilus spp*). Early life stage organisms were utilized in these tests, as this spill occurred in the spring season when young organisms were present on the shoreline (Figure 6 is a photograph of the sand crabs). Results of the sand crab bioassays were compared to the chemistry results of both surf water and porewater samples collected following the spill, to estimate the toxic effects of the spilled material on this species (Figure 7). The results indicate that concentrations of oil constituents in surf-water samples exceeded levels found to affect growth and levels found to cause mortality (lethal concentration exceeded at Los Flores; lethal concentration exceeded at multiple locations when phototoxicity is taken into account). More details on the bioassay methods and results can be found in Appendix E of the Damage Assessment and Restoration Plan.


Figure 6. Early life stage sand crabs (megalope stage, the first non-pelagic life stage) collected for use in the bioassay, or toxicity tests, seen next to three grains of sand

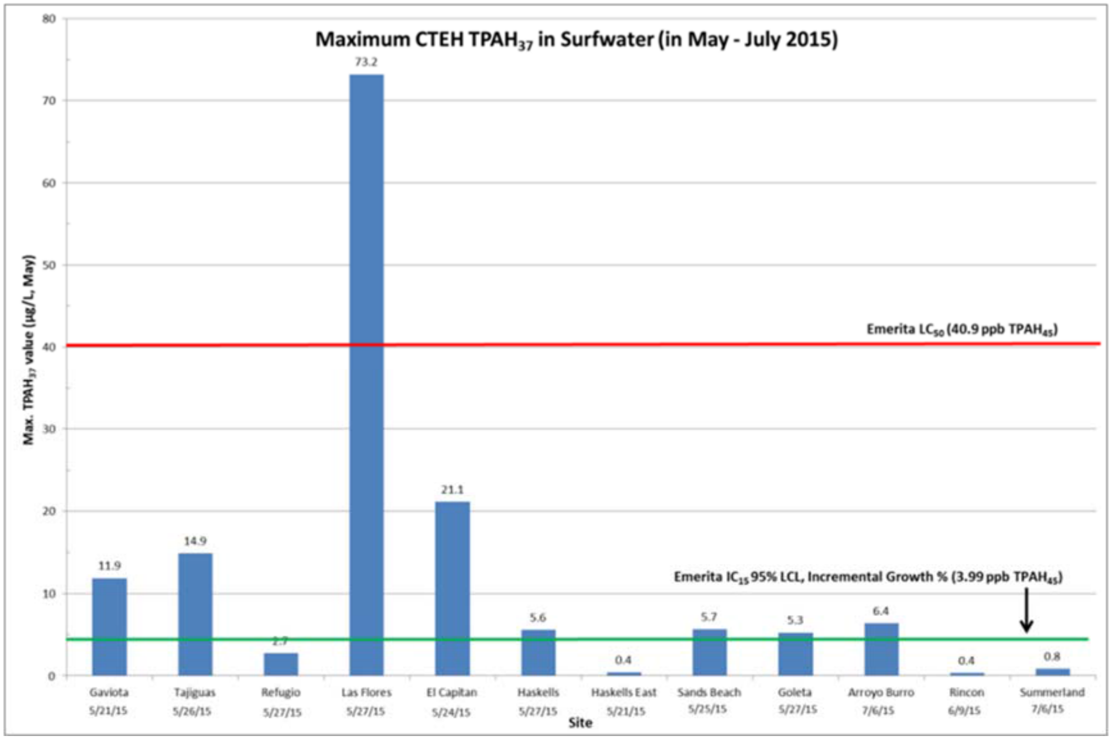

Figure 7. A. Results of bioassay work compared to maximum surf water concentrations measured in May through July 2015. For background on enhanced toxicity of PAHs to organisms with exposure to ultraviolet (UV) radiation, see Barron 2007.

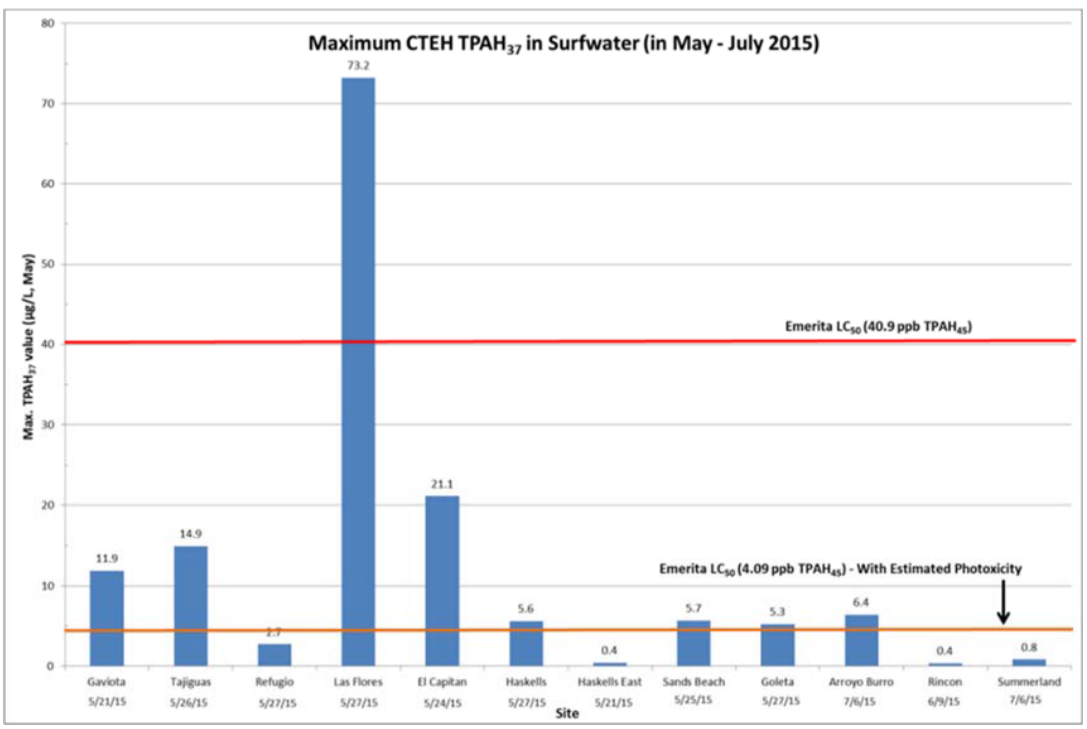

Figure 7 B. The phototoxicity benchmark shown is 10 times below the lab determined LC_{50}, and falls within the literature range of toxicity values from 2 to > 50,000 times less than non-UV exposed LC_{50} determinations for invertebrates. All other toxicity results are referenced in the bioassay report, Appendix E of the Damage Assessment and Restoration Plan.

The Trustees conducted rocky intertidal surveys to determine whether the oiling of rocky intertidal substrates (Figure 8) affected rocky intertidal communities, i.e., species composition. The surveys monitored for changes in abundances of sessile organisms, substrate, and “condition” (oil/tar presence, bleaching), within fixed plots over time (post spill and both six and twelve months post-spill). Teams surveyed permanent, “Long Term Monitoring” plots that already occurred within or adjacent to the approximate spill area footprint, allowing for comparison to historical data. In addition, several “Rapid Assessment” sites (sites selected specifically to incorporate the footprint of the oiling) were surveyed to collect data shortly after the spill, using the same protocols. Transects of each site was established, running the length of the intertidal zone, and representative photographs were taken within quadrats (Figure 9) placed throughout the transects. Each photograph was quantified for overall proportion of substrate type and species presence, as well as general condition (oiled/bleached) of each. A more detailed discussion of methods and results can be found in Raimondi et al. (2019).

Figure 8. Oiled intertidal cobble/boulders near Refugio Beach soon after spill (left). Lower intertidal cobble at Refugio Beach, January 2016, showing lingering tar in heavily oiled locations (right).

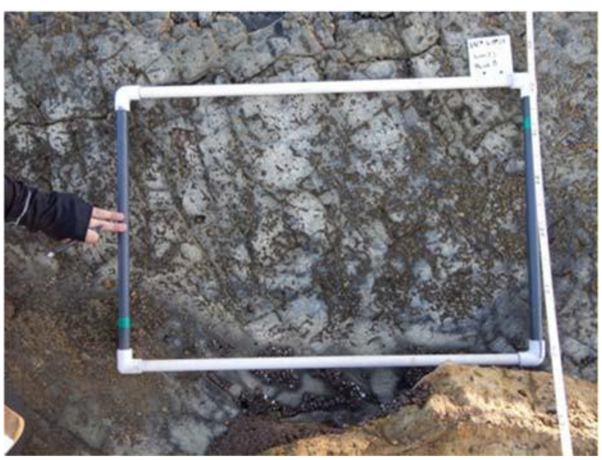

Figure 9. Rectangular quadrat used for photo-plot documentation.

Both “Long Term Monitoring” plots and “Rapid Assessment” sites were re-visited in Fall 2015 and Spring 2016 to examine for community differences, presence/absence of organisms, or proportional changes to communities or substrate. Study sites within the heaviest spill zone exhibited oiled biota, with some oil/tar persisting in anniversary sampling. In addition, minor community changes, including increases of algae species potentially indicative of oil-related impacts, were noted in the heaviest oiled locations when compared to less impacted sites (Figure 10).

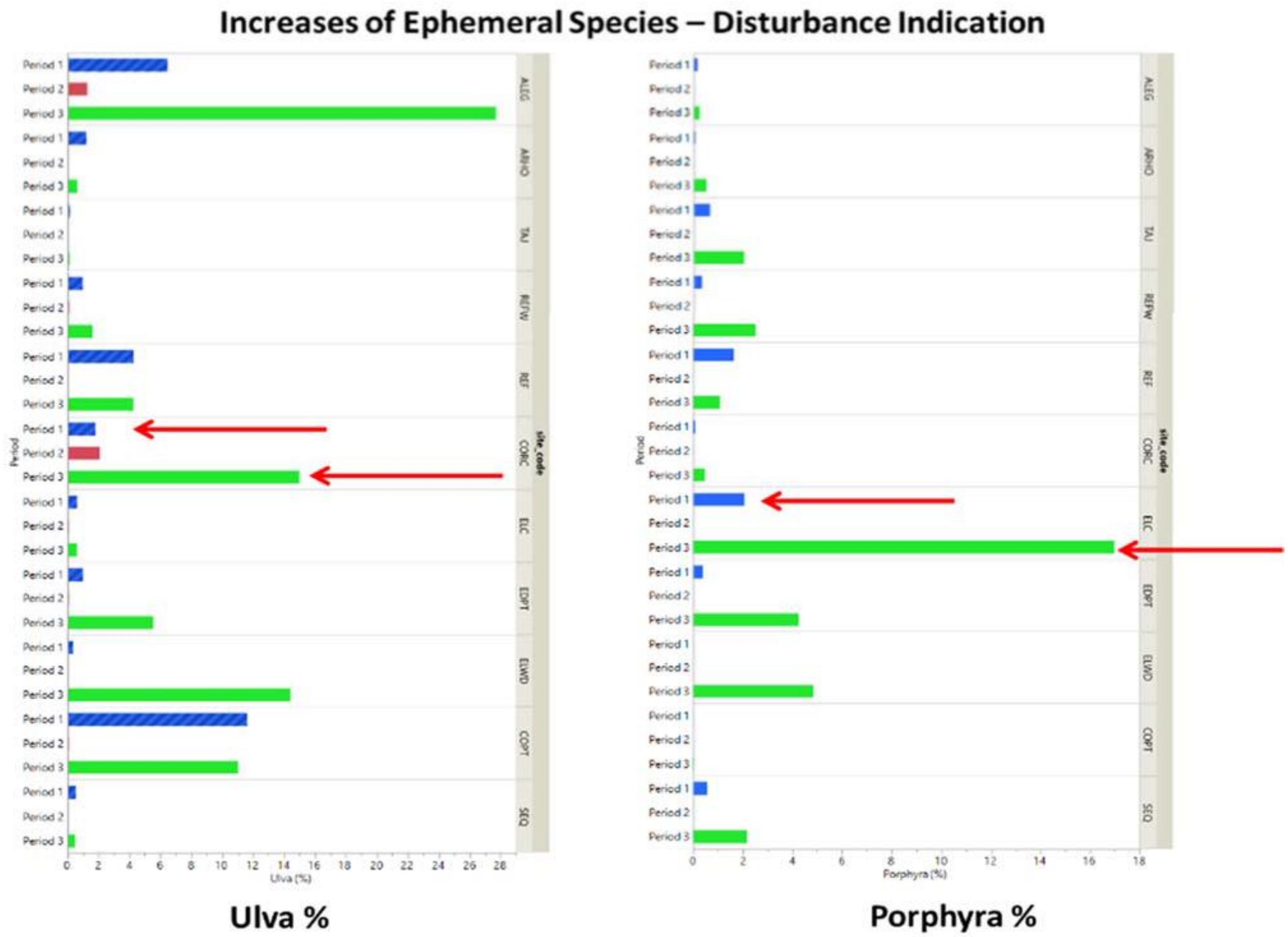

Figure 10. Proportion of *Ulva sp*. (green algae) and *Porphyra sp*. (red algae) presence across sites and time (Period 1 – post spill; Period 2 – 6mo post spill; Period 3 – 12mo post spill).

Effects of Cleanup Operations

The cleanup of the oil began not long after the release occurred, and while this removal of oil is helpful to the organisms and ecosystems affected in the long-term, there were some impacts to natural resources that were a direct consequence of the cleanup activities. The NRDA team tracked these impacts in several ways, including direct observation, review of Incident Command System (ICS) forms that documented the cleanup activities (i.e., ICS 204 forms), and the quantification of the organic and inorganic materials removed from the shoreline.

Oil removal operations included the use of several tools and techniques. Manual removal was one method employed, using crews of workers on the sandy beach portions of the shoreline. These efforts removed oil and oily materials to a visual endpoint (Figure 11).

Figure 11. Manual removal of oil and oily material from sandy shorelines. Stranded kelp, also known as wrack, was one material that was removed from shorelines.

Other cleanup efforts involved the scraping of rock and hard substrates on the shorelines, though crews were instructed not to remove visible biota in the process. Some cobble beaches were disassembled in the cleaning process, and cobble was placed in the surf zone for the final phase of the cleaning (Figure 12).

Figure 12. A highly disturbed shoreline in the process of being cleaned by the response operations workers.

The shoreline habitats were also impacted by the use of vehicles. Often vehicles were used to transport workers alongshore to worksites. This imposed physical injury to sand dwelling organisms such as talitrids, and left visible signs of tire tracks on the shoreline in some locations (Figure 13). Records were reviewed and summarized (Hubbard and Dugan, 2016) to estimate the amount of cleanup activity, quantified in days, on the shoreline habitats following the spill (Figure 14).

Figure 13. Vehicle use and tracks near Arroyo Quemado.

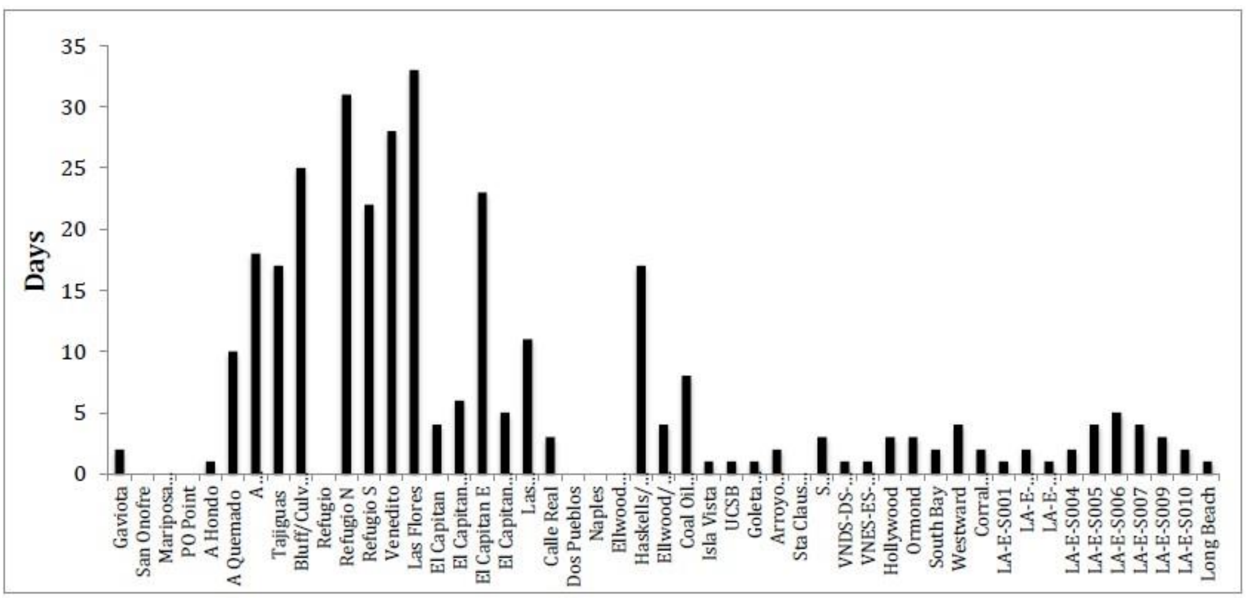

Figure 14. Documented days of clean up activity by location for 19 May to 21 August 2015.

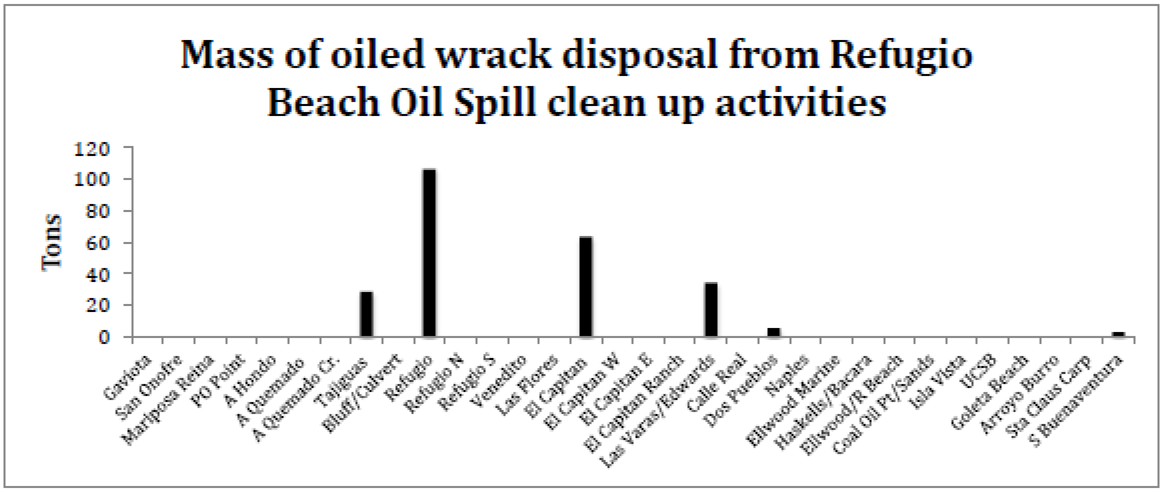

Figure 15. Mass of wrack (kelp, surf grass, and other biological materials) removed at six locations during the cleanup period. Locations are organized from West to East, or up-coast to down-coast.

The operations unit of the response effort quantified (Figure 15), the mass of oily waste removed from beaches (e.g., wrack, sand and cobble). This response operations activity directly removed wrack community organisms, as well as a food source for birds, fish, and other vertebrates that feed on the organisms in that community. These data were used in evaluating the effects of clean up activity on shoreline ecosystems.

References

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Dugan, J., 2018. Population Survey Results on Intertidal Talitrid Amphipods for the Refugio Beach Oil Spill NRDA October 2018. 9 pp. NRDA Technical Report. RBOS Administrative Record.

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Raimondi, P., Bell, C., Ammann K., Gaddam, R., Lohse, D., Douglas, M., George, M., Fletcher, N., Anderson, L., and M. Miner. 2019. Assessment of potential impacts to rocky intertidal community following the Refugio Beach Oil Spill, Santa Barbara County 05 September 2019. 166 pp. NRDA Technical Report. RBOS Administrative Record.