
BIOLOGICAL EFFECTS MONITORING DURING AN OPERATIONAL APPLICATION OF COREXIT 9580₁

Gary Shigenaka
National Oceanic and Atmospheric Administration
Hazardous Materials Response and Assessment Division
Biological Assessment Team
7600 Sand Point Way NE
Seattle, Washington 98115

Vance P. Vicente
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
Suite 1108 Banco de Ponce Building
San Juan, Puerto Rico 00918

M. Angela McGehee
University of Puerto Rico
Department of Marine Sciences
P.O. Box 908
Lajas, Puerto Rico 00667

Charles B. Henry, Jr.
Louisiana State University
Institute for Environmental Studies
42 Atkinson Hall
Baton Rouge, Louisiana 70803

Following the grounding of the barge Morris J. Berman on the northern coast of Puerto Rico in January 1994, conditional approval for the use of the shoreline cleaner Corexit 9580 was granted. One requirement was the inclusion of biological effects monitoring, particularly during the first operational application. This was intended to safeguard against unforeseen ecological consequences from the treatment - to answer the question, does the use of Corexit 9580 result in adverse biological impact beyond that caused by the oil itself? The monitoring was designed to provide immediate operational feedback (Should the application continue?) but also addressed other questions of interest for

future incidents and for further research.

Study sites were surveyed before, immediately following, and one day after treatment with Corexit 9580. No significant nearshore effects were observed, and the monitoring team recommended that operations proceed. Followup studies of organisms transplanted into the treatment area also showed few exposure-related effects. Measurable concentrations of both Corexit and oil were found in water samples collected in the treated area, and low levels of hydrocarbons were also found in sea urchins exposed to treatment runoff water. The toxicological significance of the exposure and the tissue residues were beyond the scope of this monitoring effort, but the lack of mortalities in both resident and transplanted organisms suggested a relatively minor short-term biological effect on exposed communities.

The tank barge *Morris J. Berman* grounded on the northern coast of Puerto Rico in January 1994, spilling approximately 600,000 gallons of No. 6 fuel oil. The widespread contamination of hard substrate shorelines that were both highly visible and of high recreational value led the federal on-scene coordinator (FOSC) and his shoreline assessment team to consider the use of chemical agents for shoreline cleanup operations. A field test of three products was arranged at two sites, with representatives of the Caribbean Regional Response Team (CRRT) observing the applications. The rationale, design, and results of the shoreline cleaning agent testing are described by Michel and Benggio.⁴ Based on the field trials, in which two of the three tested products significantly aided in the removal of oil from beach rock and riprap, the FOSC requested approval from the response team for operational use of shoreline cleaners on certain beaches. The team discussed the effectiveness of the products in removing the stranded *Berman* oil from beach rock and riprap, reviewed the available toxicity and cost information for the tested products, and recommended that an Exxon Co. USA cleaner, Corexit 9580, be used. The CRRT also required that a monitoring program be implemented, and suggested that the NOAA scientific support coordinator (SSC) solicit guidance from local resource experts as well as members of the response team during the design of the monitoring effort. This paper describes the framework, elements, and results of the Corexit 9580 operational monitoring program that was created and implemented during the *Morris J. Berman* spill.

Monitoring framework

Monitoring a response or cleanup activity during an oil spill is inherently difficult. Although it makes sense to evaluate both effectiveness and effect of remedial actions, in practice this can amount to well-intentioned efforts that ultimately may be of little value to responder, decision maker, or scientist.³ Even the most carefully designed and logistically well-supported monitoring efforts can yield results that are difficult for scientist and decision maker to interpret within the framework of spill response relevance (see, for example, Payne and colleagues⁵). With the limitations of previous monitoring efforts in mind, several considerations were used to frame or guide the approach to monitoring Corexit 9580 operations during the *Berman* barge spill.

Underlying question to be addressed:

Does the use of Corexit 9580 on selected oiled beach segments result in adverse biological impact over that caused by the oil spill alone?

Operational feedback as the top priority.

The clearly identified reason for implementing a monitoring program for the operational application of a shoreline cleaner was to alert the FOSC and CRRT in the event that Corexit 9580 use caused unanticipated environmental consequences. The program had to provide relatively succinct information to response and cleanup personnel to be used as the basis for "go/no go" decisions on whether to proceed with shoreline treatment.

The need for quick turnaround.

The monitoring approach had to provide an assessment of environmental acceptability *quickly*, so that operational decisions could be made in a timely manner. Monitoring techniques requiring lengthy analysis would potentially provide more information, but would not be appropriate to the need for operational relevance.

Local knowledge and participation emphasized.

Local and regional experts from the Commonwealth of Puerto Rico obviously knew the most about the nearshore resources that would be directly and indirectly affected by the shoreline cleaner application. It made sense to involve them at all levels of the monitoring effort, including the design and implementation phases.

Minimal impact on routine operations.

Although the first operational Corexit site would necessarily be more closely monitored than any subsequent sites and would require close coordination with cleanup personnel, the intent was to minimize the impact of the monitoring activity on the operations themselves. That is, monitoring of routine operations should not hinder or delay the cleanup unless clear evidence of environmental problems was observed.

Spill-of-opportunity research.

Recognizing that the clear priority in monitoring the Corexit applications was to provide the go/no go information for the FOSC and the CRRT, it also was an undeniable opportunity to learn as much as practicable about the effects of such applications in a real spill situation. Therefore, additional monitoring components, primarily chemical analyses, were undertaken and funded by NOAA to provide information that was relevant to understanding the effects of Corexit use, but which was not strictly needed or available for the immediate go/no go decision.

Monitoring program elements

Given the framework described above, a Corexit 9580 monitoring program was designed with the following components.

Descriptive nearshore surveys at first treatment site.

The primary information source for determining whether the Corexit 9580 treatment resulted in unanticipated ecological effect was a series of surveys conducted in the nearshore environment of the first test site before and after the treatment. The intent of these surveys was to note gross changes occurring in the biotic communities of the lower intertidal and shallow subtidal zones before and after Corexit use. If, in the opinion of the monitoring team, such changes took place, further Corexit use would be curtailed, and the on-site coordinator would be informed and would decide whether to continue with the treatment program. It was expected that the monitoring team, the NOAA scientific support coordinator, and the response team would be consulted by the on-site coordinator for this decision.

For both the pre- and posttreatment surveys, fixed transects would be established in the lower intertidal and shallow subtidal zones. Species counts would be made along the transects, with general observations on condition of the biota. The site would also be surveyed more broadly to provide species lists, density and diversity estimates, behavioral observations, and other descriptions of biological conditions.

The sum of these observations and documentation would be used to assess the extent of changes, if any, that occurred between surveys. The magnitude of those changes would determine the nature of the recommendation to the FOSC.

Transplant studies at first treatment site.

To investigate whether sublethal or more subtle biological impacts occurred from the use of Corexit 9580, at least two species of marine invertebrates would be collected from a clean (unoiled) area and deployed into the first treatment area. As analysis of these organisms would require one to three days, results would not enter into the immediate decision process. However, it would provide information to support or halt further operations, and would be of relevance for additional evaluation of Corexit 9580 biological effects.

The general protocol for the transplant study was to collect common intertidal organisms (sea urchins, snails, mussels) from an unoiled area and transplant them into the first treatment site. Within the site, three treatments were defined: oiled and treated with Corexit 9580, oiled and untreated, and unoiled and untreated. Groups of animals would be placed into each of the three treatment zones, and would remain in place over the duration of the first day's Corexit application. At the conclusion of the treatment, all organisms would be removed and taken to a temporary laboratory facility for examination and holding. If any mortalities were found immediately after treatment, the FOSC would be informed. Living organisms would be held in clean water for observation over a two- to four-day period, depending on observed effects, to discern any other biological consequences from the treatment.

Chemical analysis at first treatment site.

To better understand the fate and effects of Corexit 9580 and oil during shoreline treatment, chemistry sampling was planned for the first operational application of the product. Seawater samples would be collected from the three treatment zones before and after shoreline cleaning, and the

organisms transplanted into the zones would be subsampled before and after to assess potential for exposure and any resultant uptake of either oil or Corexit. Because of the laboratory work necessary to prepare and analyze these samples by gas chromatography/mass spectrometry (GC/MS), the results would not be available for on-site consideration and would not enter into the operational decision-making process. However, the monitoring study was viewed as a rare opportunity to collect information on oil and Corexit in an operational setting.

Routine biological monitoring at all Corexit 9580 sites.

Presuming that the more targeted monitoring at the first operational Corexit site indicated no significant ecological effects, a monitoring approach would be implemented for the other sites to be treated. As was the case for the monitoring plan for the first site, the intent was to guard against unforeseen environmental problems during the routine use of Corexit 9580 to mobilize the stranded *Berman* oil. However, the strategy for this monitoring activity, which would take place at all Corexit-treated sites, was more general than the plan for the first site and was based on the knowledge and experience of commonwealth biologists. In the routine monitoring, commonwealth biologists (Department of Natural Resources: DNR) would observe the Corexit shoreline cleaning operations and with the aid of a simple form, consider such fundamental questions about the environmental effect of the application as:

- What kinds of biota are present at the site?
- Are dead or dying animals present on site before, during, or after treatment?
- Are unusual animal behavior patterns observed before, during, or after treatment?
- Did any changes occur in plants or animals over the course of treatment?

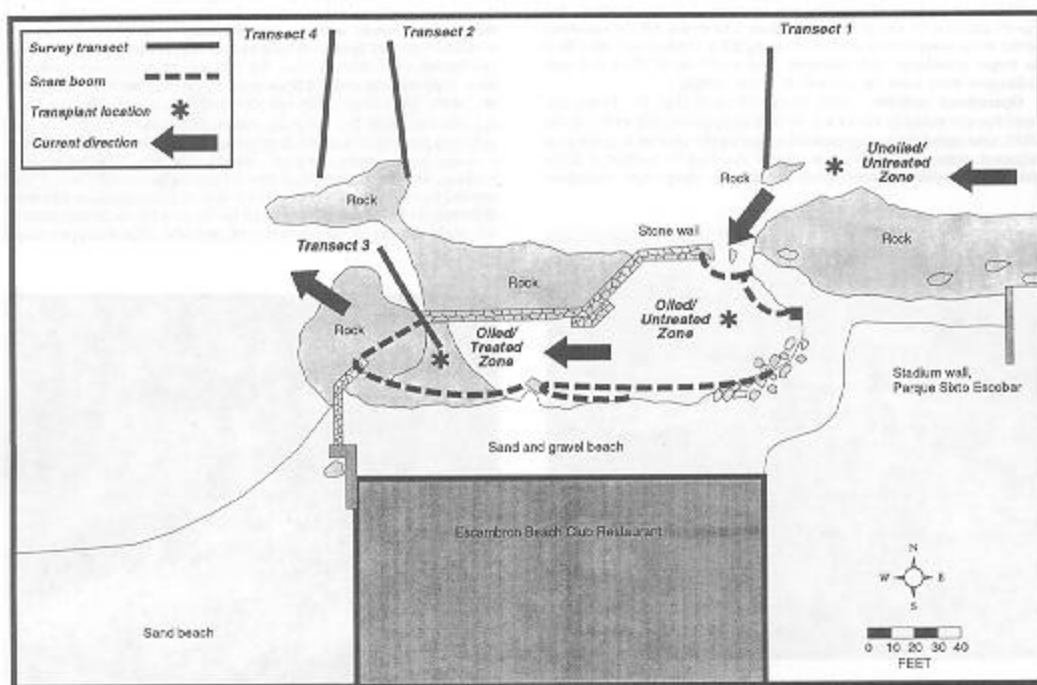
The resulting documentation was expected to be informational in nature and was not expected to constitute the same kind of go/no go signal that would be emphasized at the first site unless extraordinary conditions (massive die-offs, or unusual aggregations of animals) were encountered at or near the treatment areas. If, in the opinion of the DNR monitor, an adverse impact or potential for an impact existed, that person could halt the Corexit operation while the FOSC was apprised of the situation. The FOSC, in consultation with the NOAA scientific support coordinator and the natural resources monitor would then decide if the operation should continue.

Monitoring program implementation

Several shoreline segments meeting certain selection criteria⁴ were identified as being suitable for treatment with Corexit 9580. The initial step in implementing the FOSC- and CRRT-stipulated monitoring program was to determine which of these sites would be the first to be cleaned and, hence, would be the location of the more elaborate monitoring effort. All of the beach segments approved for Corexit use were visited by members of the monitoring team to evaluate their suitability as the first site. Based on the physical and biological attributes of each location and the requirements of the monitoring

program, a beach rock/riprap shoreline at Punta Escambron, located near the barge grounding location, was selected as being the most suitable for the following reasons.

- Unlike some of the identified shorelines, it was heavily oiled.
- The beach substrate included both beach rock and riprap.
- It included a broad intertidal area, with discrete tidepools that were isolated at low water but well flushed at high water.
- A consistent direction of water flow from east to west would assure the relative isolation of the designated oiled/treated zone at the west end of the beach, and runoff from Corexit treatment would not contaminate either the oiled/untreated or unoiled/untreated area.
- A cursory examination of intertidal biota indicated a relatively diverse community present.
- The site provided easy access for both personnel and cleanup equipment.



1. *Plan view of site selected for first operational application of Corexit 9580 during the Morris J. Berman spill, showing locations of monitoring transects, transplant and snare boom locations, and prevailing current flow*

Treatment and monitoring methods

Transect surveys.

Four permanent transects were established in the nearshore environment of the designated

monitoring site. They were generally oriented perpendicular to the shoreline, running from the intertidal zone into the subtidal zone, and ranged between roughly 15 and 30 feet in length. Transects were marked with colored line strung between nails at each end. Figure 1 shows the locations and orientation of transects on site.

The day before the scheduled Corexit treatment at Punta Escambron, the monitoring team enumerated biota along the four survey transects and made general biological observations on conditions at the site. Immediately following treatment on February 1, the transects and site were resurveyed. This was repeated on the following day as well.

Transplant experiment.

In preparation for the transplants at the first treatment site, divers traveled to Punta Maldonado, east of San Juan and away from major spill impacts, and collected red sea urchins (*Echinometra lucunter*), two species of snails (tessellated nerite, *Nerita tessellata*, and zebra periwinkle, *Littorina ziczac*), and scorched mussels (*Brachiodontes exustus*). The collected organisms were transported from Punta Maldonado in fresh seawater to a temporary laboratory facility at the U.S. Coast Guard command center, where they were placed into 10-gal aquariums for holding (Figure 2) until their deployment during the Corexit application at Punta Escambron. Approximately one hour before treatment commenced, the collected animals were moved on site, loaded into nylon mesh dive bags, weighted with dive weights, and placed in each of the three defined oiling and treatment zones. At each of the three treatment zones, the following numbers of animals were deployed: 50, red sea urchins, 40, tessellated nerites, 40, zebra periwinkles, and 80, scorched mussels.



2. _____
*Aquariums containing red sea urchins, *Echinometra lucunter*, in temporary laboratory facility established at U.S. Coast Guard command center*

Chemistry.

Pretreatment water samples were collected for chemical analysis about one and a half hours before application of the Corexit 9580 product. Cleaned 1-L brown glass bottles were used for water samples. Four samples were collected in the designated oiled/treated zone, two from the oiled/untreated zone, and one from the unoiled/untreated zone.

Chemical analysis of samples was performed at the Institute for Environmental Studies at Louisiana State University. GC/MS analysis of the water samples was performed using EPA Method 625, modified to target petroleum hydrocarbons. The methods of MacLeod and colleagues were used for analysis of tissue samples.²

Operational methods.



3. *Punta Escambrón monitoring site, facing west, showing site preparation and initial application of Corexit 9580 at west end of beach - person on the right is monitoring airborne concentrations of volatile hydrocarbons.*

After being informed that the Punta Escambron site would be the first to be treated operationally with Corexit 9580, contracted cleanup personnel prepared the area by wrapping an adjacent restaurant building in plastic sheeting to protect it from overspray, positioning snare boom around the prospective treatment areas to contain and collect any mobilized oil and Corexit, and installing the necessary pumps and hoses for the shoreline treatment (Figure 3).

Application of Corexit 9580 began during the afternoon of February 1. The treatment took place on a falling tide, beginning at a tidal elevation of about 1 foot and ending at about 0 feet. Based on a recommended application rate of 1 gal/100 ft², 25 gal of Corexit were allocated for cleaning the approximately 2,500 ft² Punta Escambron site. An approximately 100 ft² area was initially sprayed with Corexit, allowed to soak for 30 minutes, and then was washed with high-pressure hot water, reading 175 ° F and 1150 psi at the heater/pump unit.

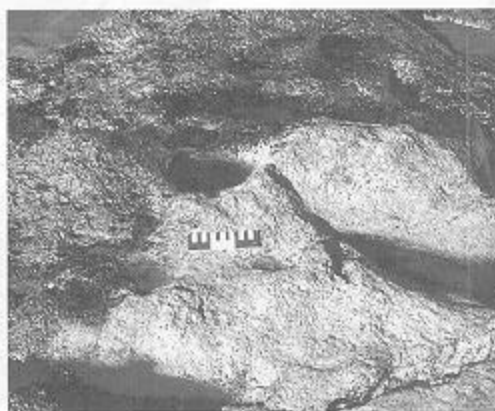
At the direction of the monitoring team, treatment began on the western end of the beach (Figure 3). As noted previously, the east-west water flow through the area would prevent treatment runoff from entering other designated treatment zones to the east. The original plan of the monitoring team was that when the area around the oiled/treated transplants was completed, application and washing operations would be halted so that all three transplant deployments could be recovered, and water chemistry samples could be collected. In practice, the Corexit treatment was more time-consuming than originally anticipated; and by the end of the work day, only the shoreline around the oiled/treated zone at the west end of the beach had been completed. However, this was consistent

with the monitoring plan in that transects were examined, transplants recovered, and chemistry samples collected after operations had been secured for the day on the beach. This treatment should have maintained the integrity - the apparent segregation of oiling and treatment - since no Corexit 9580 washing took place east of the designated oiled/treated station.

Results

Observations immediately following treatment.

The shoreline cleaner test previously conducted in San Juan had indicated that use of the products would increase the efficiency with which *Berman* oil would be removed from substrate such as that at the Punta Escambron monitoring site.⁴ Results after the first day of operations confirmed these expectations: observations made by cleanup personnel responsible for the application of Corexit 9580 and subsequent shoreline washing indicated that the substrate was in fact coming clean, and that although pitted rock was still dirty (stained), the Corexit treatment was working. Some unevenness of cleaning was noted by the cleanup workers, who attributed it to differences in the amount of Corexit 9580 applied to the shoreline (because oil removal effectiveness had been demonstrated in the tests conducted on January 19, no formal attempt was made to quantify the amount of oil removed at the first operational site). In the approximately 165 minutes of treatment, roughly 250 ft² were cleaned. Figure 4 shows a section of beach rock at the end of the work day, with the cleaned and uncleaned portions clearly demarcated.



4.

Treated (lower right) and untreated (upper left) beach rock following Corexit 9580 application at Punta Escambrón



5. *Tidepools in Corexit 9580-treated portion of monitoring site, showing clouded water resulting from treatment and washing - object in center of photo is the oiled/treated transplant deployment.*

With the falling tide over the course of treatment, the tidepools on the west side had become isolated from the prevailing current flow across the site. Following the application of Corexit 9580 and the pressure washing around these pools, the water was visibly clouded and murky brown in color (Figure 5). Interestingly, several juvenile fish (believed to be sergeant majors, *Abudefduf saxatilis*; surgeonfish, *Acanthurus bahianus*; and possibly goat fish, *Pseudopeneus maculatus*) were observed in the pools swimming in the cloudy water and showing no obvious signs of narcosis or other impairment.

After completion of the shoreline treatment operations for the day, transplanted animals were removed from the three treatment zones. The length of time that the organisms had been in place and exposed to the treatments was about three and a half hours (205 minutes). Two biologists resurveyed the four permanent transects, and characterized general conditions in the intertidal and shallow subtidal areas around the monitored beach. Replicated water samples were collected from each of the treatment zones for chemical analysis. Tissue chemistry samples from transplanted organisms were subsampled from the bagged deployments.

The survey of the transects and general area at the treatment site before and immediately after Corexit application and washing showed little discernible difference in biological conditions. Moreover, as discussed above, resident fish in the tidepools that were receiving waters for concentrated runoff from treatment showed no evidence of ill effect.

Results from transplant experiment.

Mesh bags containing the transplanted invertebrates were transported in clean seawater, and with aeration, back to the U.S. Coast Guard command center, where the temporary laboratory was located. Sea urchins from each of the three treatment zones were placed into separate 10 gal aquariums containing clean, aerated seawater (Figure 2), while snails and mussels were placed into separate 2.5 gal tanks. From each deployment, 15 urchins, 20 nerites, 20 periwinkles, and 40 mussels were reserved for chemical analysis by wrapping in aluminum foil and freezing.

The remaining animals were held overnight in the tanks and observed the following morning for effects of exposure to the Corexit process.

Echinometra;BI sea urchins.

Table 1 summarizes results observed in the laboratory for red sea urchins deployed in the transplant experiment. In general, the urchins showed little evidence of effect that could be attributed to either oil or Corexit exposure. On February 2, the day after the treatment, no mortalities were observed in any of the treatment groups. All urchins were prodded by hand to determine adherence to the glass surface of the aquariums. All adhered. All urchins showed active movement of their pedicellariae.

On February 3, one urchin was noted as dead in two of the three tanks: that containing unoiled/untreated, and that containing oiled/treated animals. Testing of the righting abilities of all remaining urchins was performed by placing each aboral side up; all righted themselves within 30 minutes. No other physical or behavioral abnormalities were observed.

Nerita;BI snails.

Table 2. summarizes laboratory results for the tessellated nerite snails. These organisms showed no sign of adverse effect from the transplant experiment. The day after treatment and exposure, the opercula of all snails was tested with a probe to gauge retractor muscle function. All appeared to be functioning properly. After being placed on a dry surface with opercula upward, *Nerita* from all treatment groups had righted themselves and begun crawling within an hour. On the next day, February 3, all *Nerita* from all treatment groups again righted themselves within one hour.

Littorina;BI snails.

Table 3 summarizes laboratory results from the transplant experiment for *Littorina ziczac*, the zebra periwinkle. The small size of the snails made examination difficult, but they were subjected to the same tests as were the larger nerite snails. The periwinkles may have shown some adverse effect from exposure to oil and Corexit treatment, as three (of 20 total) individuals exposed to treatment showed little evidence of activity in the aquarium on February 2. These were regarded as mortalities in Table 2. A higher incidence of inability to orient was also observed for the Corexit treatment animals. On February 2, all snails appeared to be intact and closed, but in two hours some of the *Littorina* had not moved (Table 3). On February 3, the ability of the littorine snails to right themselves was again tested, with similar results for inability to do so.

Brachiodontes;BI mussels.

Table 4 summarizes laboratory results for scorched mussels, *Brachiodontes exustus*, deployed in the transplant experiment. The mussels showed an interesting but apparently transient effect that may or may not have been the result of exposure to the Corexit treatment runoff.

Mussels were inspected for shell integrity. Any open shells or broken shells were counted as dead. One each mortality was recorded on February 2 and February 3 in the unoiled/untreated tank

(open shell), and in the oiled/untreated tank (broken shell).

The extent to which the mussels had extruded new byssal threads for anchoring themselves was also evaluated among the three groups. There appeared to be an oil/treatment-related effect on the number of mussels demonstrating the ability to attach themselves with byssal threads. However, as shown in Table 4, the potential effect was not observed to the same extent upon examination of the mussels on the next day.

Chemistry results.

Because of the time required for sample preparation and analysis, the results for water and tissue chemistry were not available in time for operational or scientific consideration on scene in San Juan. However, they are of interest for interpreting observed results of exposure along the transects and in the transplant experiments, and for inferring potential biological effect in future applications.

Water chemistry.

Water chemistry results confirmed observations of apparent dispersal of Corexit 9580 and *Berman* oil into the water column indicated by its cloudy brown appearance during both the shoreline cleaner test and the operational monitoring study. Water samples collected prior to treatment in all zones and in the oiled/untreated zone and the unoiled/untreated zone after treatment all yielded analytical results for targeted aromatic hydrocarbons below detection limits of 0.01 mg/L. In contrast, water samples collected from the oiled/treated zone following Corexit 9580 application and washing on February 1 resulted in concentrations of aromatic hydrocarbons ranging from 5.2 to 26 mg/L. In the large tidepool where the transplants were deployed for the oiled/treated zone, concentrations after treatment ranged between 5.2 and 12 mg/L. Other water samples were collected in smaller tidepools that were subjectively more impacted by treatment runoff (that is, were small volume and contained cloudier water), and these showed higher concentrations, ranging from 16 to 26 mg/L.

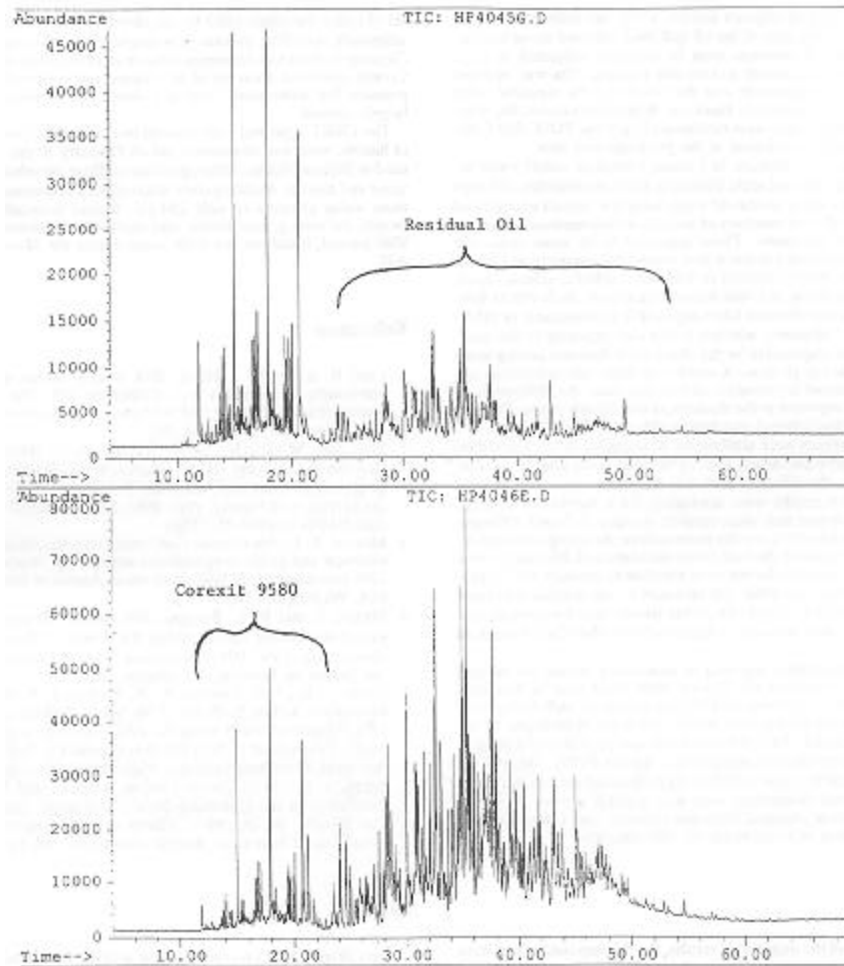
Figure 6 shows the chromatographic profile of hydrocarbons measured in post-treatment water samples from the oiled/treated zone. The chromatogram illustrates the differences in the ratio of Corexit to oil from different samples. The relative ratio of Corexit 9580 to oil ranged between 1:4 and 1:1, and may reflect the variability in application rate that could be expected during operational use of the shoreline cleaner.

Tissue chemistry.

Although tissue samples were collected from sea urchin, snail, and mussel deployments in the transplant experiment, only sea urchins yielded sufficient amounts of material for interpretable chemical analysis.

No significant differences in concentration among the treatment groups could be detected in the sea urchin tissues. Concentrations of total target aromatic hydrocarbons fell between 0.65 and 1.00 ng/mg. The small number of samples - one each composited from each treatment zone - preclude any serious discussion of differences among the concentration results. However, source fingerprinting analysis suggests:

- Urchins from both oiled/treated and oiled/untreated zones reflected some exposure to *Berman* oil; and,
- Sea urchins from the unoiled/untreated zone contained a low level of background hydrocarbon contamination not attributable to the *Morris J. Berman*.



6.

Chromatographic profiles of hydrocarbons detected in posttreatment water samples, with residual oil and Corexit 9580 identified

Occupational monitoring results.

Occupational exposure to volatile hydrocarbons was measured during the application of Corexit 9580 at the west end of the site (Figure 3). At head and chest elevations, measured concentrations were 9 ppm and 5 ppm, respectively. Other measurements near the treated substrate itself ranged from 15.5 to 34 ppm. With the personal exposure limit set at 700 ppm, the exposure from the Corexit application was not considered to be a problem.

Discussion and conclusions

The overriding justification for implementing a monitoring program during the operational application of Corexit 9580 in San Juan was to provide rapid feedback to the FOSC and other response personnel on unforeseen environmental effects that could result from use of the product. With this goal in mind, the monitoring effort was designed to give a "quick and dirty" assessment of environmental effect. The sampling and reporting was neither rigorous, nor statistically defensible in the sense of being a standard scientific study. It was, however, viewed as a reasonable compromise between the need for simple operational feedback and as a way to generate information that might be of value in guiding future responses and more-focused scientific research efforts. Because approval for operational application of chemical shoreline cleaners has been rare, it seemed important to maximize the amount of usable information generated by the monitoring study - thus, the variation in approaches and the kind of data assembled.

The transect surveys and the general site observations made by the experienced local biologists indicated little discernible effect immediately after the chemical shoreline cleaning. No important changes were noted along the fixed transects, and there were no signs of widespread mortalities elsewhere in the treated portion of the site. Species of fish such as sergeant majors, which had suffered from fish kills during the early days of the oil spill itself, showed no such sensitivity to Corexit/oil mixtures even in tidepools subjected to large amounts of treatment runoff and no tidal flushing. This was, in many ways, a worst-case exposure, one that would not be repeated often under normal circumstances. Based on these observations, the monitoring team was unanimous in recommending to the FOSC that Corexit use be allowed to continue at the predesignated sites.

It is possible that exposure to Corexit treatment runoff water resulted in slightly elevated acute toxicity to zebra periwinkles, although the differences among treatment zones were not distinct enough and there were insufficient numbers of animals for replications to make a more definitive statement. There appeared to be some indication among the transplanted mussels that short-term exposure to Corexit 9580 treatment runoff resulted in transient sublethal effects, manifested by an inhibition in byssal thread attachment. Such effects have been noted in other bivalves when exposed to contaminants or otherwise stressed.^{1,7} However, whether in this case exposure to the treatment runoff was responsible for the observed differences among treatment zones is not at all clear. A number of other external factors can affect byssal thread attachment; and in this case, the differences in water flow and exposure at the three zones was directly proportional to the degree of byssal thread attachment observed. Even if the initially observed differences were attributable to exposure to the Corexit/oil solution, they were also nearly gone by the second day after treatment. In other words, the effect, if real, was transient.

The chemistry results were interesting for a number of reasons. First, they confirmed that some variable mixture of Corexit 9580 and oil could be expected to enter the water column during operational use of the shoreline cleaner. Second, bioaccumulation of this mixture into sea urchins, an organism known to be sensitive to exposure to oil and to chemical cleaners,² was either not extensive or was

mediated by rapid biological depuration. Third, the urchin tissues were not pristine, and indicated some prior exposure to hydrocarbons other than *Berman* oil or Corexit.

Given the constraints imposed in monitoring during an oil spill response, we considered the Corexit 9580 experience in San Juan during the *Morris J. Berman* spill to be a success. A well-defined and relatively simple overall goal permitted the team of biologists to use results from a modest data collection effort and professional judgment to evaluate environmental acceptability for the FOSC. Beyond the basic go/no go call that resulted from the main component of the study, we hope that the monitoring work may provide a basis for better understanding how chemical shoreline cleaners, and Corexit 9580 in particular, behave in a real-world oil spill situation.

Postscript

On the basis of the monitoring results, the cleanup contractors were essentially given preapproval to use Corexit 9580 in cleaning a selected set of rocky shorelines oiled by the *Morris J. Berman* spill. However, ultimately very little product was employed for this purpose. Why? Cleanup workers had determined that most of the oiled shoreline in the Corexit-approved areas could be cleaned relatively well using high-pressure hot water alone, and as a result, the chemical cleaner was largely unused.

The CRRT approved a subsequent test of Corexit 9580 for cleaning of historic walls and structures, and on February 10 the chemical was used at Tajamar Ruins. Although it did facilitate the release of oil from stone and mortar, historic preservation experts recommended a maximum water pressure of only 250 psi. Rather ironically, therefore, despite the testing, monitoring, and approval procedures that Corexit 9580 passed, it did not see wide usage during the *Morris J. Berman* spill.

1. Opinions or assertions expressed in this paper are solely those of the authors and do not necessarily represent the views of the U.S. Government, NOAA, the University of Puerto Rico, or Louisiana State University. Mention of trade names or commercial products does not constitute an endorsement or recommendation for their use.

2. A die-off of red sea urchins shortly after the *Berman* spill occurred was attributed by many to initial water column exposure to water-soluble portions of the oil; the authors observed ulcerations on sea urchins strikingly similar to those described by Smith⁶ after sea urchins were exposed to hydrocarbon-based shoreline cleaners following the *Torrey Canyon* spill.

References

1. Carr, R. S. and D. J. Reish, 1978. Studies on the *Mytilus edulis* community in Alamitos Bay, California: VII. The influence of water-soluble petroleum hydrocarbons on byssal thread formation. *The Veliger*, v21, n2, pp283 - 287
2. MacLeod, W. D., Jr., D. W. Brown, A. J. Friedman, D. G. Burrows, O. Maynes, R. W. Pearce, C. A. Wigren,

and R. G. Bogar, 1985. Standard Analytical Procedures of the NOAA National Analytical Facility, 1985 - 1986. NOAA Technical Memorandum NMFS F/NWC-92. 121pp

3. Mearns, A. J., this volume. Confirming response effectiveness: An overview and guide to operational monitoring. *Proceedings of the 1995 International Oil Spill Conference*, American Petroleum Institute, Washington, D.C.
4. Michel, J. and B. L. Benggio, this volume. Testing and use of shoreline cleaning agents during the *Morris J. Berman* oil spill. *Proceedings of the 1995 International Oil Spill Conference*, American Petroleum Institute, Washington, D.C.
5. Payne, J. R., J. R. Clayton, C. R. Phillips, J. R. Robinson, D. Kennedy, J. Talbot, G. Petrae, J. Michel, T. Ballou, and S. Onstad, 1991. Dispersant trials using the *PAC Baroness*, a spill of opportunity. *Proceedings of the 1991 International Oil Spill Conference*, American Petroleum Institute, Washington, D.C., pp427 - 433
6. Smith, J. E., 1970. *Torrey Canyon* Pollution and Marine Life. Cambridge at the University Press, Cambridge, England. 196pp
7. Van Winkle, W., Jr., 1970. Effects of environmental factors on byssal thread formation. *Marine Biology*, v7, n2, pp143 - 148

Author

Gary Shigenaka is a marine biologist with the Biological Assessment Team of NOAA/HAYZMAT, based in Seattle, Washington. He provides remote and on-scene scientific support on biological issues to NOAA scientific support coordinators and the U.S. Coast Guard during spills of oil and hazardous materials.

Table 1. Laboratory examination of red sea urchins, *Echinometra lucunter*,¹ transplanted into Corexit 9580 treatment zone

	Mortalities		Adherence		Pedicellariae		Righting ability, 30 min	
	Count	%	Count	%	Count	%	Count	%
Feb. 2								
Unoled/untreated	0	0	35	100	35	100	NE	NE
Oiled/untreated	0	0	35	100	35	100	NE	NE
Oiled/treated	0	0	35	100	35	100	NE	NE
Feb. 3								
Unoled/untreated	1	2.9	34	100	34	100	34	100
Oiled/untreated	0	0	35	100	35	100	35	100
Oiled/treated	1	2.9	34	100	34	100	34	100

1. N = 35

2. of total alive

NE = not examined

Table 2. Laboratory examination of tessellated nerite snails, *Nerita tessellata*,¹ transplanted into Corexit 9580 treatment zone

	Mortalities		Operculum		Righting ability, 1 hr	
	Count	%	Count	%	Count	%
Feb. 2						
Unoled/untreated	0	0	20	100	20	100
Oiled/untreated	0	0	20	100	20	100
Oiled/treated	0	0	20	100	20	100
Feb. 3						
Unoled/untreated	0	0	20	100	20	100
Oiled/untreated	0	0	20	100	20	100
Oiled/treated	0	0	20	100	20	100

1. N = 20

Table 3. Laboratory examination of zebra periwinkle, *Littorina ziczac*,¹ transplanted into Corexit 9580 treatment zone
Unoled/Untreated

	Mortalities		Operculum		Righting ability, 2 hr	
	Count	%	Count	%	Count	%
Feb. 2						
Unoled/Untreated	0	0	20	100	19	95
Oiled/untreated	0	0	20	100	18	90
Oiled/treated	3 ₂	15	20	100	14	70
Feb. 3						
Unoled/untreated	0	0	20	100	19	95
Oiled/untreated	0	0	20	100	18	90
Oiled/treated	0	0	20	100	16	80

1. N = 20

2. Snails not moving on bottom of tank

Table 4. Laboratory examination of scorched mussel, *Brachiodontes exustus*,¹ transplanted into Corexit 9580 treatment zone
Unoled/Untreated

	Mortalities		Byssal attachment	
	Count	%	Count	% ²
Feb. 2				
Unoled/untreated	1	2.5	30	76.9
Oiled/untreated	1	2.5	15	38.5
Oiled/treated	0	0	1	2.5

Feb. 3

Unoled/untreated	1	2.5	36	92.3
Oiled/untreated	1	2.5	28	71.8
Oiled/treated	0	0	23	58

1. N = 40

2. of total alive