REMOVING OIL AND SAVING OILED MARSH GRASS USING A SHORELINE CLEANER

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ABSTRACT: A new shoreline cleaner, which was specially developed during the cleanup of the Valdez spill in Alaska, was tested to determine its effectiveness in removing oil from Louisiana Gulf Coast marsh grass thus minimizing the oil impact. Intact plugs of Spartina alterniflora containing living plants, roots, and soil microbial communities were collected from salt marshes and transferred to a greenhouse. Plant photosynthesis, respiration, and stomatal conductance were monitored during the cleanup of the shoreline cleaner. South Louisiana crude oil was less toxic but caused almost total plant mortality unless the plants were cleaned with the shoreline cleaner. Corexit 9580 prevented mortality of oiled red mangroves (Rhizophora mangle) by removing oil that otherwise suffocated roots. Corexit 9580 shoreline cleaner, developed during the cleanup in Alaska of the Valdez spill, is a low toxicity, low dispersion cleaner whose cleaning effectiveness and low toxicity have been confirmed in tests at Environment Canada as shown in Table 1. This paper examines the effectiveness of Corexit 9580 for cleaning oiled Spartina alterniflora marsh by use of this shoreline cleaner in a real oil spill.

Marshes are an important part of riverine, estuarine, and coastal ecosystems. A significant amount of petroleum is refined, stored, or transported through these areas and some marshes are therefore subject to occasional fouling with oil. Marshes provide fish and wildlife habitat and can improve water quality. Thus, there is generally great public attention and pressure to minimize negative impacts of oil in marshes.

Chemical and mechanical methods are available to minimize negative effects of oil in wetlands. Oil can be physically removed from the wetland or concentrated with absorbent materials or burned. But wetlands are particularly vulnerable to mechanical damage during removal operations. Determining a cleaning strategy therefore involves trade-offs balancing physical damage to the marsh and oil toxicity. Short-term damage to wetland ecosystems can be acceptable when it prevents long-term ecological impacts. Sometimes, the best approach may be no action because physical damage and toxicity problems associated with the available cleaning techniques may be greater than allowing the oil to remain in the wetland.

A need therefore exists for techniques that reduce adverse impacts of oil on wetlands without causing additional toxicity problems or affecting adjacent ecosystems. Teas and colleagues recently showed that Corexit 9580 prevented mortality of oiled red mangroves (Rhizophora mangle) by removing oil that otherwise suffocated roots. Corexit 9580 shoreline cleaner, developed during the cleanup in Alaska of the Valdez spill, is a low toxicity, low dispersion cleaner whose cleaning effectiveness and low toxicity have been confirmed in tests at Environment Canada as shown in Table 1. This paper examines the effectiveness of Corexit 9580 for cleaning oiled Spartina alterniflora marsh by use of this shoreline cleaner in a real oil spill.

Materials and methods

Vegetation samples. Intact plugs of living salt marsh were collected from Louisiana salt marshes and acclimated to greenhouse conditions. The plugs were 15 cm in diameter and 20 to 30 cm deep; they contained rooted plants roughly 40 cm tall. Plugs were collected by inserting a 30 cm long, sharpened PVC pipe into the marsh, removing the pipe and enclosed soil, and placing a PVC cap over the bottom of the plug. Plugs were returned to the greenhouse where they were stored in 38 L plastic tubes filled with diluted artificial seawater. Seawater was at 8 ppt salinity, similar to the bayou water where the plugs were collected. Plugs were watered with tap water as needed to maintain 5 to 10 ppt salinity.

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Table 1. Toxicity and cleaning effectiveness of various cleaners

<table>
<thead>
<tr>
<th>Product</th>
<th>Toxicity to rainbow trout (LC50 ppm)</th>
<th>Oil removal in lab tests (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corexit 9580</td>
<td>&gt;6000</td>
<td>42</td>
</tr>
<tr>
<td>Value 100</td>
<td>4250</td>
<td>2</td>
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<tr>
<td>BP 1100X AB</td>
<td>2900</td>
<td>23</td>
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<tr>
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<td>Corexit 7664</td>
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<td>650</td>
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<tr>
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<td>521</td>
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</tr>
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<td>8</td>
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<td>IDX 20</td>
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<td>Oil Spill Eater</td>
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<td>Bioversal</td>
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</tr>
<tr>
<td>Nokomis 3</td>
<td>110</td>
<td>13</td>
</tr>
</tbody>
</table>

1. After Fingas et al
2. Ranked by toxicity

Oiling and cleaning vegetation. The South Louisiana crude or bunker C oil was applied to vegetation. The South Louisiana crude was weathered by storing the oil in uncovered pans inside a greenhouse. Oil was applied to individual plants using a cotton glove dipped in oil. Oil remained on the vegetation from 1 to 3 days. Corexit 9580 was used to remove oil from vegetation. Cleaner was applied to vegetation, approximately 4 oz of chemical per test core, with a manual squeeze-type hand sprayer, and allowed to soak for 15 minutes. Plants were then gently washed with a garden hose. Oil-contaminated seawater was replaced with clean seawater after cleaning.

Whole plug gas exchange measurements. Photosynthesis rates for each plug were estimated from the difference between the rates of CO2 change in light and dark chambers. Light and dark chambers were placed over entire plugs in standing water to make an airtight chamber. Whole plug gas exchange samples were collected from the headspace of each plug at least once before day 0, when the oil was applied. Stem count data were also collected prior to oiling. Gas samples were collected day 0, day 1, day 2, day 14, day 29, and day 44. Whole plug photosynthesis and whole plug respiration data were analyzed as repeated measures. This statistical method allows correlated observations, such as those collected from the same plug on different days, to be analyzed properly for differences among plugs. Data were analyzed with SAS software.

All aboveground biomass was harvested on days 111 to 113. Those data were analyzed using a completely randomized design. This experimental design is best suited for detecting small differences that persist over the course of an experiment.

Results—Oil appeared to have a toxic effect on the plants, but new leaves quickly appeared. These new leaves originated primarily from the tops of oiled stems. The cleaner removed almost all traces of oil from the vegetation. The cleaner also appeared to have a delayed, temporarily adverse effect on the plants. Leaves became yellow and stunted; some died, others eventually recovered.

Aboveground biomass varied 2-fold among the plugs by the end of the experiment and no significant differences were detected among the treatments (Chi-square = 3.7034, df = 4, P > Chi-square = 0.4476). There was great variability in whole-plug photosynthesis and whole-plug respiration rates among plugs (Figure 1). However, statistical analyses indicated no significant differences among the treatments in whole-plug photosynthesis or whole-plug respiration; differences were attributed to substantial variations in the amount of foliage from the study plugs.

• Whole chamber gas exchange—Gas samples were collected from the headspace of each plug at least once before day 0, when the oil was applied. Stem count data were also collected prior to oiling. Gas samples were collected day 0, day 1, day 2, day 14, day 29, and day 44. Whole plug photosynthesis and whole plug respiration data were analyzed as repeated measures. This statistical method allows correlated observations, such as those collected from the same plug on different days, to be analyzed properly for differences among plugs. Data were analyzed with SAS software.

When data were pooled across treatments over the course of the experiment, oiled plants had significantly reduced stomatal conductance (Figure 4) and no photosynthetic activity. The leaves on which these measurements were taken died by day 38. The new shoots that subsequently emerged had stomatal conductance and net photosynthetic rates similar to the control plants, showing no detectable stress effects.

The application of cleaner after one and two days had similar effects on stomatal conductance but cleaning after one day resulted in significant improvement of net photosynthesis recovery relative to plants cleaned after two days. Application of cleaner alone did not affect mean leaf conductance (Figure 4), but caused significant reductions in net photosynthesis (Figure 5). It is important to note that while cleaner application caused reductions in net photosynthesis, plants treated with cleaner only or oiled and cleaned after one day did not show massive leaf death as seen in the oiled plants. By the end of the experiment, natural leaf regeneration replaced all dead leaves, which partly explains why there were no differences in biomass among the treatments.

Experiment Two. Eight plugs were oiled with the same South Louisiana crude used in Experiment 1, but with additional weathering that resulted in a total weight loss of 33 percent. There were two treat-
ments: oiled and cleaned, and oiled and uncleaned. This experiment also differed in that these plants were oiled from top to bottom, which simulated oiling during foul weather conditions. Four of the plugs were cleaned the next day.

**Whole chamber gas exchange**—Gas samples were collected from all eight plugs on day 0 immediately following oiling, and on days 1, 8, 34, and 47. Whole-plug photosynthesis and whole-plug respiration data were also analyzed using a repeated measures analysis of variance design.

**Results.**—Complete oiling without cleaning caused massive, rapid death to all existing leaves. Leaf death in the oiled and cleaned plants did not appear as extensive as in the oiled and uncleaned plants. But as in Experiment 1, all plants appeared to recover by the production of new leaves produced by existing stems.

Aboveground biomass at the end of the experiment averaged 41 g/plug in uncleaned plugs and 34 g/plug in cleaned plugs, but the difference was not significant ($P = 0.8852$). Dead aboveground biomass averaged 37.2 g/plug in oiled plugs and 30.8 g/plug in oiled and cleaned plugs; the difference was not significant ($P = 0.0545$).

Whole-plug photosynthesis averaged 237 µL CO$_2$/min in cleaned plugs and 353 µL CO$_2$/min in uncleaned plugs, but variability among plugs was so great that the difference was not significant ($F = 2.2659$, 1 and 30 df, $P = 0.1439$). Respiration averaged 147 µL CO$_2$/min in cleaned plugs and 247 µL CO$_2$/min in uncleaned plugs, but again variability among plugs was so great that the difference was not significant ($F = 2.0503$, 1 and 26 df, $P = 0.1632$).

**Leaf area gas exchange**—Stomatal and photosynthetic response measurements on plants were conducted on 6 sample leaves per treatment on days 1, 9, 19, 34, and 53 following treatment initiation.

**Results**—Photosynthetic rates of cleaned leaves were significantly greater than in uncleaned leaves (Figure 6). Beginning on day 34, all original leaves were dead, and the gas exchange mea-
measurements were conducted on leaves that had emerged after the treatments were applied (Figure 7). The newly emerged leaves had similar gas exchange measurements in the two treatments (Figures 8 and 9).

Experiment Three. Eight plugs were randomly assigned to one of three treatments: completely oiled with bunker C, completely oiled and cleaned, and unoiled and uncleaned (control). Two plugs were assigned to the control treatment; three plugs were assigned to the other treatments.

- **Whole chamber gas exchange**—Gas samples were collected on day 5. Aboveground biomass was harvested on day 49.

- **Results**—Even though the bunker C formed an extremely thick coating on the plants, the cleaner removed virtually all the oil. Plants in the uncleaned plugs did not recover. Unlike oiling with South Louisiana crude, stems as well as leaves died. Original stems produced no new leaves and only five wilted—new stems emerged from oiled plants within seven days of oil applications. Thus, whole-plug photosynthesis rates quickly recovered from oiling with South Louisiana crude. This was not the case when plants were oiled with bunker C, which caused almost complete plant mortality. Whole-plug photosynthetic rates in oiled plants were less than 50 percent the rates in unoiled plants. Oiled stems did not produce new leaves as they did when they were fouled with South Louisiana crude. Several new stems emerged in one oiled plug, but there were too few to counter the death of all other stems and leaves during the course of our experiment.

Whole-plug respiration did not appear to be affected by either South Louisiana crude or bunker C. This agreed with previous studies that found that oil had little effect on soil microbial communities. As noted, however, the whole chamber method used was capable of detecting large or modest effects.

**Effects of cleaning oiled Spartina alterniflora.** These experiments indicated that cleaning with Corexit 9580 was beneficial because clean-
Figure 6. Time-course response of net photosynthesis to various treatments in Experiment 2—Measurements were conducted on the existing leaves during the 30-day period following treatment initiation. \( O + C \) = oiled and cleaned; \( O \) = oiled but not cleaned (bars not visible because values were close to zero)

Figure 7. Time-course response of net photosynthesis to various treatments in Experiment 2—Measurements were conducted on new leaves that emerged during the 30-day period following treatment initiation. \( O \) = oiled and not cleaned, \( O + C \) = oiled and cleaned after 1 day

Figure 8. Mean values of stomatal conductance in new tissue developed after treatment initiation in Experiment 2—Values represent the mean for measurements over the experimental period. \( O \) = oiled and not cleaned, \( O + C \) = oiled and cleaned after 1 day

Figure 9. Net photosynthesis in new tissue developed after treatment initiation in Experiment 2—Values represent the mean for measurements over the experimental period. \( O \) = oiled and not cleaned, \( O + C \) = oiled and cleaned after 1 day

Evolving Technologies

Response implications. In responding to oil spills in \( S. \ alterniflora \) marshes, the responding agency should consider how much tissue is covered and the type of oil. \( S. \ alterniflora \) marshes oiled with South Louisiana crude should recover without cleaning, but recovery should be enhanced by cleaning with Corexit 9580. On the other hand, \( S. \ alterniflora \) marshes oiled with bunker C require cleaning to survive, because of the severity and persistence of the adverse effects of the oil. Corexit 9580 removes the oil and allows \( S. \ alterniflora \) to recover. Regardless of the type of oil to be cleaned, it appears that the cleaner should be applied as soon as possible following an oil spill to prevent massive plant tissue death and to speed up the recovery of normal plant functions.

Marshes fouled with South Louisiana crude and bunker C benefit
Figure 10. Production and respiration in Experiment 3 with bunker C

Figure 11. Aboveground biomass at the end of Experiment 3

from cleaning with Corexit 9580, but variations in the level of toxicity of the different oils suggest different response strategies when resources are limited. When *S. alterniflora* marshes are fouled with South Louisiana crude, limited resources might best be spent on other aspects of cleaning because the marsh will recover as shown by the present studies as well as the previous studies. However, when *S. alterniflora* marshes are fouled with bunker C, limited resources might best be spent on cleaning the marsh because it may not recover otherwise. Specific data are needed to determine the toxicity of South Louisiana crude and Corexit 9580 to other important marsh plant species before response strategies can be formulated for other marsh types and other oil types. For instance, the Louisiana Offshore Oil Port pipeline carries a mixture of crude oils across more than 25 miles of marshes, the majority dominated by other species, such as Panicum hemitomon and *Spartina patens.*

Summary

Coastal, estuarine, and riverine marshes are occasionally fouled by oil from navigation channels, pipelines, and storage facilities. Fouling can stress or kill vegetation, but some available cleaning strategies may be more harmful than taking no action. This project investigated the effectiveness of Corexit 9580 for cleaning *Spartina alterniflora.*

Intact plugs containing living plants, roots, and soil microbial communities were collected from Louisiana salt marshes and transferred to a greenhouse. Whole-plug photosynthesis, whole-plug respiration, stomatal conductance, and leaf area gas exchange were monitored following different fouling and cleaning scenarios. Experiment 1 evaluated cleaning plants that were partially oiled with Louisiana South crude. Experiment 2 evaluated cleaning plants that were completely oiled with Louisiana South crude. Experiment 3 evaluated cleaning plants that were completely oiled with bunker C.

Plant recovery depended on the degree of fouling and type of oil.

Figure 12. Response of stomatal conductance in *Spartina alterniflora* to various treatments using bunker C oil in Experiment 3—Values represent the mean for measurements over the experimental period; a = control (neither oiled or cleaned), b = oiled and cleaned after 1 day, c = oiled and not cleaned. Values across treatments labeled by different letters are significantly different at the 0.05 level.

Fouling with bunker C caused almost total plant mortality unless the plants were cleaned. South Louisiana crude was less toxic, but cleaning enhanced recovery because cleaned plants had more photosynthetic activity to help speed recovery. Collectively, these studies indicated that oiled *S. alterniflora* marshes benefited from cleaning with Corexit 9580; other important species also may benefit from such cleaning.
Acknowledgment

This research was supported in part by Exxon Research and Engineering and the Louisiana Education Quality Support Fund, Grant No. LEQSF (94-95)-ENH-PLEX-01.

References