ECOLOGICAL IMPACTS OF A WETLAND OIL SPILL AND BIOREMEDIATION EXPERIMENTS

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ABSTRACT: *The Texas General Land Office (TGLO) proposed using a wetland impacted by the San Jacinto River October 1994 oil spill as an experimental bioremediation field study site. Monitoring the effect of bioremediation on ecological community structure was included as a part of the comprehensive study. Monthly benthic sampling to study the ecological effects of bioremediation occurred from November 1995 to October 1996. Before bioremediation experiments were initiated in March 1996, benthic species abundance and richness increased from a July 1995 baseline study; however, the monthly data still indicate an ecological system under stress. Although mean densities of benthic invertebrates fluctuated monthly, the relative pattern of densities for experimental and control plots remained the same prior to and after the bioremediation treatments. Declines in benthic mean monthly densities occurred at both the control and the experimental plots after bioremediation began, requiring an examination of additional stress factors. The dominant benthic species was the polychaete* Laeonereis culveri, *which accounted for 60.2% of the benthic organisms collected. Analysis of data concerning bioremediation effects on ecological community structure is necessary to ensure that bioremediation does not further damage an already impacted ecological community. The limited preliminary data set presented here indicates that the bioremediation treatments used in this study did not significantly affect benthic communities.*

Coastal wetlands are ecologically important, providing food, habitat, and protection from predation for many species. Texas coastal wetlands function as a valuable estuarine resource for Gulf of Mexico fisheries. Wetlands also function in nutrient cycling and act as filters, removing contaminants and organic pollutants from waters flowing into the Gulf of Mexico (Duke and Kruczynski, 1992). Oil spills can have serious consequences in wetlands that function as nursery or spawning grounds for estuarine organisms. Factors affecting these consequences include seasonal activity, organism life cycles, the composition and amount of oil, and the duration of oil exposure. Sediment composition can also dictate the rate of dissemination of spilled hydrocarbons (NAS, 1975; Mielke, 1990; Crowe, 1994). Permeating into sediments up to 70 cm deep, traces of oil can be detected in organisms at multiple trophic levels as long as 1 year after spills occur (Burns and Teal, 1971, *in* NAS, 1975).

The exposure of estuarine organisms that are sensitive to oil-contaminated sediments during critical life stages can seriously affect an ecosystem; invertebrates, including crustaceans and benthic organisms, are significantly affected by exposure to spilled oil (NAS, 1975; Chasse, 1978; Mancini *et al.*, 1995). Repercussions from oil spills may be long-lasting; oil tar mats believed to have originated from the *Ixtoc I* spill surfaced for as long as a year along the Texas coast.

Since oil spills damage wetland ecosystems and affect critical habitat, effective cleanup methods are essential to minimize ecological impacts. Bioremediation has been effective in laboratory studies and shows promise in restoring habitat contaminated by hydrocarbon spills. The first extensive field-testing of bioremediation occurred after the 1989 *Exxon Valdez* oil spill in Prince William Sound, Alaska (Bragg *et al.*, 1992). Although previous bioremediation field studies had been conducted, results had often proved inconclusive, and many studies lack sufficient monitoring of the effects of bioremediation on ecological communities (Gardner *et al.*, 1979; Mearns, 1993). Field test data concerning the efficacy of bioremediation treatments on the *Apex* oil spill in upper Galveston Bay, Texas, in August 1990 proved inconclusive (Mearns, 1991, 1993). Components such as weathering of oil and microbial degradation rates can be affected by cold temperatures (Mielke, 1990); therefore, further field tests were necessary to determine the effectiveness and effects of bioremediation in warm, temperate Texas climates.

Other cleanup method studies have concluded that detergent emulsification of oil, removal of oiled biota, and burning of oiled areas are less effective than leaving the oiled areas untreated, although not all researchers are in agreement (Freedman, 1989; Houghton *et al.*, 1993; Tunnell *et al.*, 1994; Mearns, 1995). Studies investigating the effects of oil cleanup methods following the *Exxon Valdez* spill showed that methods such as hot-water high-pressure washing considerably altered communities of macroinvertebrates that were otherwise unaffected as a result of the oil spill (Houghton *et al.*, 1991).

Although nutrient addition increases the rates of microbial degradation of hydrocarbons by three to five times, it may pose problems for the ecological community (Bragg *et al.*, 1992). Nutrients used in bioremediation could be toxic to organisms at all levels, and previous studies call for further monitoring of the biological effects of bioremediation. Field studies monitoring the fauna and flora of an impacted site throughout the bioremediation process are necessary to assess the ecological effects of a spill and the long-term effect of bioremediation treatments on a coastal ecosystem (Mearns, 1995). In addition, the water quality following oil spills is best determined through observation of biota (Crowe, 1994). The sensitivity of benthic macroinvertebrate communities to disturbances supports their use as indicators of environmental stress (Harrel *et al.*, 1976). The rapid response of benthic organisms to disturbances is generally due to restricted mobility and high population growth rates (Longley, 1994).

This study originated when the Houston area was inundated by 30 to 35 inches of rain in mid-October 1994; the rain flooded the San Jacinto River. Flood debris struck and ruptured pipelines located in the river, spilling over 2 million gallons of fuel, crude oil, and gasoline (Casteel, 1995). The spill provided an excellent opportunity to establish an interdisciplinary bioremediation field study site in the impacted area. The Texas A&M University (TAMU) environmental engineering team began monitoring the site immediately after the spill to study the extent of petroleum hydrocarbon contamination. Ecological studies conducted by Texas A&M University—Corpus Christi (TAMU—CC) began

March 1995. The purpose of the ecological study was to monitor the effects and long-term impacts of oil spills and bioremediation on an ecological community structure. The entire ecological study not only encompasses the benthic community presented here; it is a comprehensive study of nekton, avian usage, vegetation, and phytoplankton.

Other biological studies of the San Jacinto River are sparse, and studies of nearby areas have seldom involved long-term monitoring (Gillard, 1974; White *et al.*, 1985; Harper, 1992). Because historical data were lacking, a baseline study was conducted to permit a limited analysis of community structure and organisms in Parker's Cove before a yearlong ecological study was begun (Wood *et al.*, 1995). The baseline provided ecological data that were lacking in previous benthic studies and helped determine the effects of the petroleum hydrocarbon spill in the coastal wetland areas.

Study area

Parker's Cove lies on the San Jacinto River in Harris County, Texas, approximately 24 km north of the San Jacinto River and Houston Ship Channel Gulf entrance (29°47′9″N, 95°04′2″W) (Figure 1). The cove is a tidally influenced, brackish wetland, and substrate is composed of a 25-mm layer of fine, loose clay above a homogeneous particle sand layer. The cove is approximately 300 m long by 100 m wide, and the depth is approximately 1.5 m. Flooding and contamination rendered the area to an even less pristine state, making Parker's Cove an ideal site for experimental bioremediation field studies. A reference control site across the river and to the north of Parker's Cove was also established (Texas General Land Office, 1995). Two control sites within the cove that were only slightly oiled by the original spill and not treated during the bioremediation studies were also established and used in this study.

The sampling design for bioremediation experiments at Parker's Cove, established by the TAMU environmental engineering research team, consisted of six blocks containing three plots each. Plots measured 5 m by 5 m in area and were constructed of wooden scaffolding. Each plot within an individual block underwent a different bioremediation treatment during testing; this plan allowed for the collection and analysis of six replicate samples of each treatment type. The Parker's Cove control sites (plots 32 and 33) are located along the east shoreline. Block 3 (plots 8, 10, and 12) is located along the west shoreline, and the reference control (OC) is located approximately 1.6 km across the river (Figure 2).

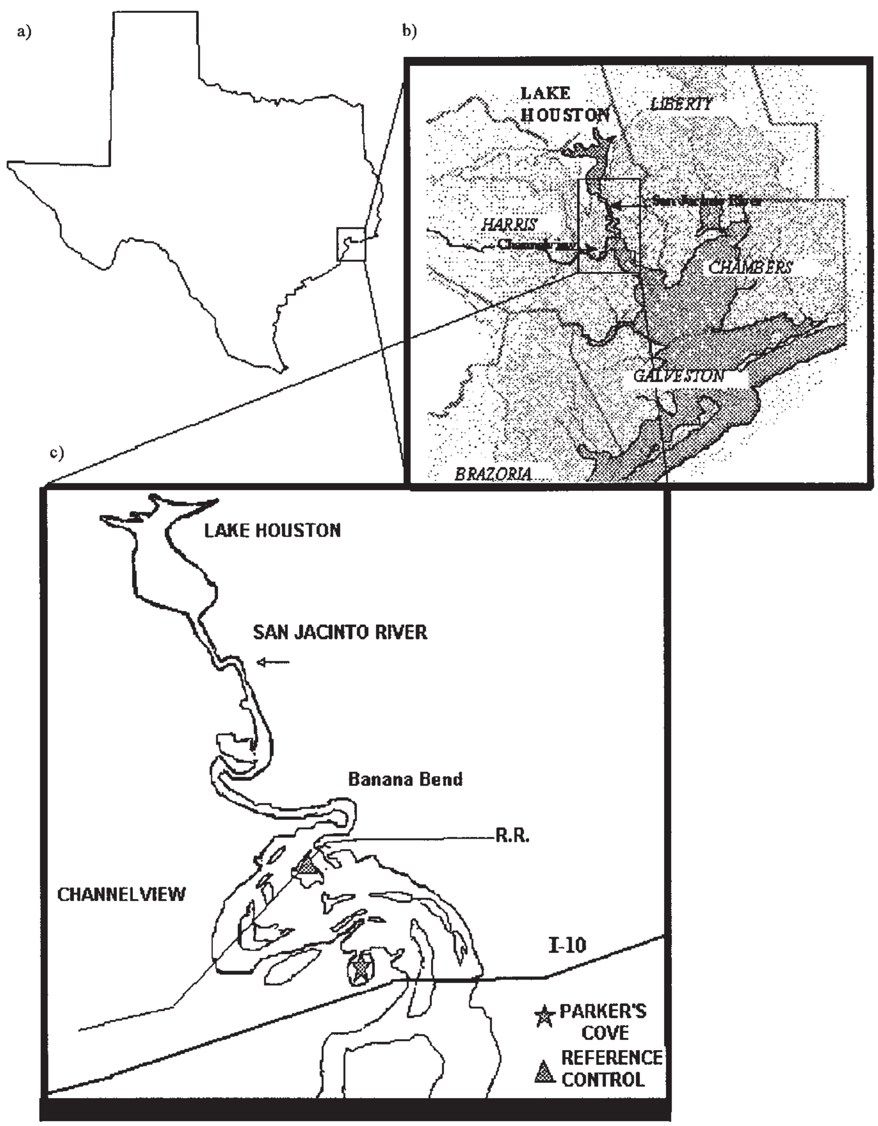

Figure 1. Maps detailing the location of Parker's Cove study site: (*A*) the Texas Gulf Coast, (*B*) Galveston Bay area, and (*C*), San Jacinto River

Methods

Over the course of this study, benthos, nekton, and plankton samples, as well as bird surveys, were obtained monthly to monitor the ecological health of the site prior to, and following, bioremediation treatment. Benthic samples were collected intertidally at 9 of the 18 study plots and at 4 additional intertidal benthic locations, 2 Parker's Cove control sites, and the original reference control site. Hydrological parameters of water temperature, salinity, and pH were also recorded each month at both Parker's Cove and the reference control site.

Core samples of benthic organisms were obtained using a 10-cm-diameter PVC core inserted 10 cm into the substrate. Two replicate core samples were taken monthly from the intertidal area within 1.0 m of the front of each plot. Samples were fixed in a 10% formalin solution stained with the protein stain rose bengal to facilitate laboratory analysis at the Center for Coastal Studies laboratory at TAMU-CC. Laboratory analysis consisted of washing samples through nested sieves (minimum mesh = 0.5 mm) and then sorting, identifying, and counting organisms before drying for biomass amounts at 90°C for 2 days.

Data presented in this paper consist of monthly benthic samples collected from block 3 (plots 8, 10, and 12), the Parker's Cove control sites (PCC = plots 32 and 33), and the original reference control site (OC) for the period November 1995 through April 1996, and July 1996. Application of oil and bioremediation treatments began in March 1996, but treatments were not applied to the reference control site or to Parker's Cove controls. Oil was applied to all plots in block 3; plot 12 received no nutrients or oxidants, plot 8 was treated with both nutrients and oxidants, and plot 10 was treated with nutrients only. Treatments were reapplied throughout the experiment to maintain acceptable levels.

SPSS for Windows statistical programs run at the 95% confidence level ($p \pm 0.05$) were used to analyze benthic data. Data analysis consisted of converting abundance to mean monthly density. After log-transformation (density +1), one-way ANOVAs produced all faunal density analysis.

Results

Water temperature, salinity, pH, and dissolved oxygen values were recorded from both Parker's Cove and the reference control site on sampling days. Water temperatures ranged from a low of 9.7°C in February 1996 to a high of 29.2°C in July 1996. Because of drought conditions in Texas, limited amounts of fresh water were released from the dam upriver and salinities varied monthly, generally increasing from 8.6 ppt in November 1995 to a high of 17.3 ppt in April 1996. Following rainfall in July 1996, which alleviated area drought conditions, salinities then decreased to 7.8 ppt. Dissolved oxygen ranged from 5.9 to 11.7 mg L^{-1} over the course of the study, while pH remained fairly stable, ranging from a high of 8.6 in March 1996 to a low of 7.4 in January 1996.

Benthic core samples produced a total of 5499 individual organisms, yielding an actual dry weight biomass of 3.6 grams. A total of 35 species representing four phyla were identified; 17 species of annelids, primarily polychaetes, dominated core samples. Arthropods consisted of 9 species of crustaceans and 4 species of insects, and mollusks yielded 3 bivalve and 1 gastropod species. Nemerteans represented the remaining phyla, with 1 unidentified species collected.

Comparisons of block 3, PCC, and OC showed that block 3 produced 29 species, the highest number of benthic species collected; PCC produced 27; and OC produced 15 total species collected. Mean monthly density was highest at PCC, ranging from 764 to 23,331 organisms

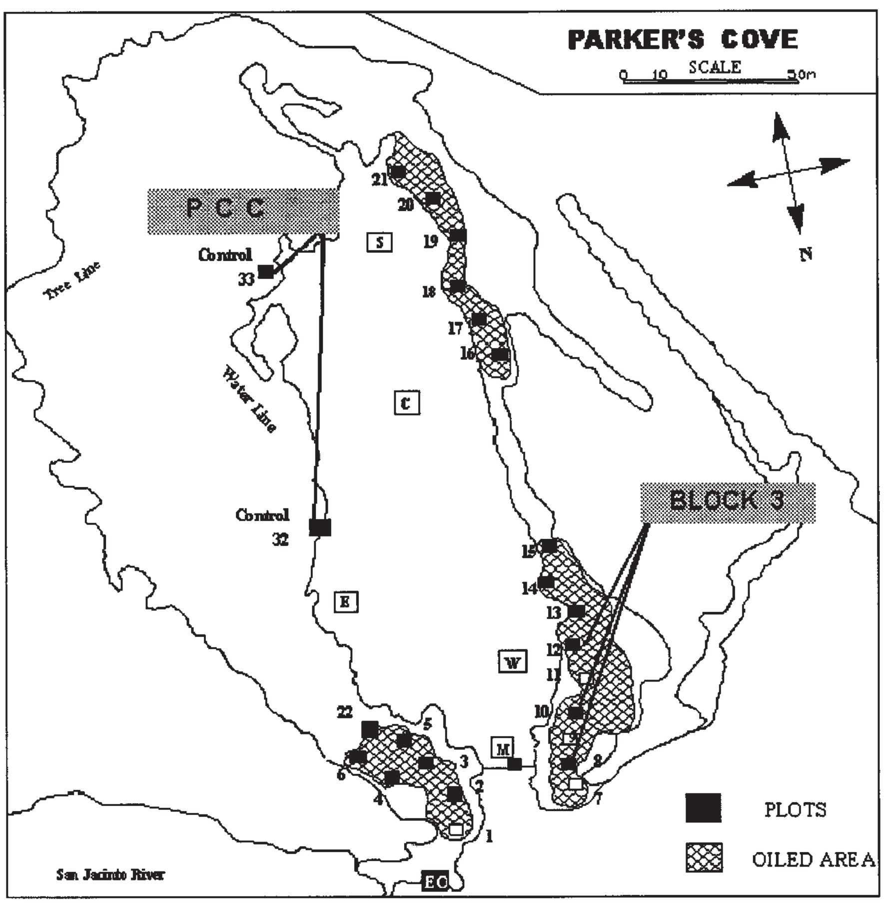

Figure 2. Maps detailing the location of sampling locations within the Parker's Cove bioremediation field study site

m^{-2} and producing an overall mean monthly density of 12,173 organisms m^{-2} collected (Figure 3). Mean monthly density of major taxa at PCC included 10,495 polychaetes m^{-2} (86% of PCC organisms), 628 crustaceans m^{-2}, 282 mollusks m^{-2}, and 768 other benthic organisms m^{-2} collected. Mean monthly biomass was also highest at PCC, ranging from 0.3 to 11.3 g m^{-2}. This yielded a mean monthly biomass of 7.7 g m^{-2} for the PCC control sites over the sampling period. Polychaetes dominated mean monthly biomass amounts, accounting for 7.1 g m^{-2} (92.5%) of the total biomass for the two stations combined.

Block 3 yielded an overall mean monthly density of 7260 organisms m^{-2} and was composed of 5478 polychaetes m^{-2} (75.5% of block 3 organisms), 133 crustaceans m^{-2}, 373 mollusks m^{-2}, and 1276 other benthic organisms m^{-2}. Block 3 mean monthly density ranged from 2122 to 9973 organisms m^{-2} (see Figure 3). Mean monthly biomass ranged from 2.4 to 7.4 g m^{-2}, which produced an overall mean biomass amount of 4.2 g m^{-2}. Polychaetes also dominated biomass amounts and accounted for 89.5% or 3.8 g m^{-2} of the mean monthly biomass amount. The lowest mean monthly density recorded was 3883 organisms m^{-2}, and occurred at OC, where the range was from 955 to 7003 organisms m^{-2} (see Figure 3). The mean monthly density of major taxa at OC was represented by 2510 polychaetes m^{-2} (64.6%), 36 crustaceans m^{-2}, 227 mollusks m^{-2}, and 1110 other benthic organisms m^{-2}. This location yielded a slightly higher biomass amount than block 3, with a mean monthly biomass amount of 4.6 g m^{-2} being recorded. Mean monthly biomass amounts ranged from 0.5 to 14.2 g m^{-2}. As was seen in the other locations, polychaetes dominated biomass amounts, producing 4.1 g m^{-2}, which represented 88.9% of the mean monthly OC biomass. No significant differences ($p = 0.215$) in mean monthly density existed between locations during the sampling period.

Comparison of monthly species richness shows block 3 gradually declining each month until February 1996, then remaining the same in March, after application of oil and bioremediation treatments. PCC monthly species richness also remained constant from February until March. All blocks experienced decline in species richness from March to April and from April to July 1996. Comparison of monthly mean densities from November 1995 until March of 1996 shows PCC to be greater than block 3, and block 3 greater than OC. Whereas the mean densities and abundance of PCC and block 3 rose each month through February, both locations declined slightly in March. OC mean monthly density for each month continued to rise and fall with each month from November 1995 until July 1996, declining in December.

Overall comparison of individual plots show that density and biomass were highest at plot 32 (PCC), with a mean monthly benthic density of 15,069 organisms m^{-2} and a mean monthly biomass of 9.7 g m^{-2}. Plot 12 of block 3 followed, producing a mean monthly benthic density of 10,759 organisms m^{-2} and a mean monthly biomass of 5.1 g m^{-2}. The lowest mean monthly benthic density of 3883 organisms m^{-2} occurred at the reference control site (OC) located across the river from Parker's Cove (Figure 4). However, the mean monthly biomass amount for OC was the third highest at 5.7 g m^{-2}. Although no significant differences existed between plot densities ($p = 0.237$), all samples were dominated by large numbers of polychaetes being collected, and this taxa typically represented greater than 52.0% of all organisms occurring in the cores.

Comparison of species richness in block 3 plots shows that plot 10 (oil and nutrient application) yielded the highest species richness, with 22 species collected. Species richness was only slightly lower in plots 8 (oil, nutrient, and oxidant) and 12 (oil only), with 20 species collected for each location. Plot 12 showed a gradual decline in species richness from a high December 1995 of 14 species until February 1996 with 8 species. After bioremediation treatments were applied in March, plot 12 experienced an increase in species richness. Species richness of PCC plots, which had no oil or bioremediation treatments, were comparable to block 3 plots, with plots 32 and 33 producing a total of 19 and 21 species, respectively. April mean densities decreased at all sites except for plot 8, and all sample sites experienced a dramatic decrease in monthly densities in July 1996.

Monthly densities of plots in block 3 decreased from February to March after application of oil and bioremediation treatments, but plot 10 density began decreasing in January 1996, prior to treatments, and continued decreasing from February until March. However, after application of the oil and bioremediation treatments, there were no statistically significant differences between the three treated plots in block 3 ($p = 0.763$).

Three annelid organisms, two species of polychaetes, and unidentified oligochaetes accounted for 82.5% of all the organisms collected. The polychaetes *Laeonereis culveri* and *Hobsonia florida* accounted for 60.2% and 11.6%, respectively. The unidentified oligochaetes produced the remaining 10.7% of the total number of organisms collected. These species also contributed 89.4% of the total biomass amount, with *L. culveri, H. florida,* and oligochaetes yielding 83.0%, 5.4%, and 1.0%, respectively. The influence of these three species, especially *L. culveri*, dictated the spatial (Figure 5) and temporal (Figure 6) trends seen in these data.

Discussion and conclusions

The goal of this study was to discern the effects of bioremediation treatments on ecological communities of a southern coastal wetland. As is often the case in oil spills, there were no prior historical data on the ecological community structure of the study site. However, a baseline study conducted 9 months after the 1994 oil spill, as well as site monitoring of ecological communities for 4 months prior to bioremediation field-testing, allowed some statistical assessment of the ecological con-

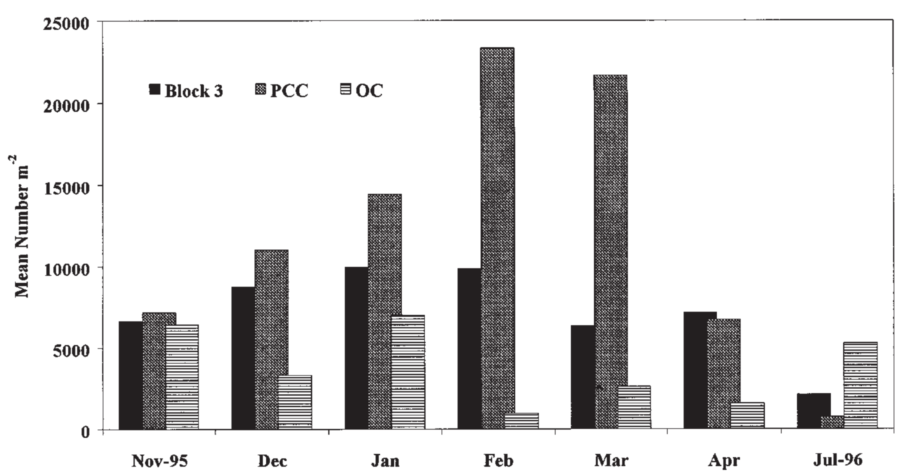

Figure 3. Mean monthly benthic density at block 3, Parker's Cove control (PCC), and original control (OC), November 1995 through April 1996 and including July 1996

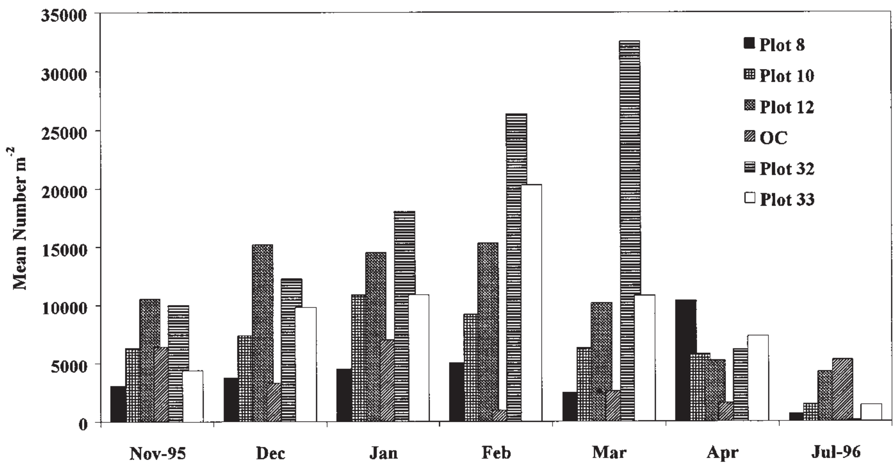

Figure 4. Mean monthly benthic density at plots 8, 10, 12, original control (OC), plot 32, and plot 33, November 1995 through April 1996 and including July 1996

dition of Parker's Cove. Analysis of the remaining replicate benthic data, as well as the nektonic data, and continued monthly ecological monitoring of the site will help to further determine if these limited data set assumptions are valid.

Other concerns with the limited data presented here are recognized. In both the baseline study and monthly sampling, the reference control (OC) samples yielded densities and species richness much lower than those samples from within Parker's Cove. One possible explanation for this could be that even though OC escaped severe oiling during the 1994 spill, there may be other contamination impacting OC that is not influencing the Parker's Cove study site downstream. In addition, the ecological health of the ecosystem was determined solely on the preliminary benthic data set; however, replicate benthic data and additional ecological data such as nekton and bird usage are being analyzed and will be presented at a later date.

These preliminary data permit a comparison of plots and control sites within Parker's Cove before and after bioremediation treatments began in March 1996. The data also allow for a limited examination of the effects of different experimental treatment types (oil; oil and nutrients; oil, nutrients, and oxidants) on the benthic community structure of block 3, and also allow for comparisons between the effect of these treatments on benthic communities and nontreated controls (PCC) within the cove.

July 1995 baseline data showed the cove to be a fairly depauperate area, with low species richness and abundance. It is difficult to conclusively determine a cause for this condition, but it is most likely due to a composite of impacts to the ecosystem. Both man-made and natural perturbation have occurred, such as the 1994 flood and oil spill, the seasonal impact of reduced abundance during summer, when benthic populations tend to be limited, and the general poor health of the Galveston Bay system because of previous contamination and pollution. In addition, continual stress from impacts such as fluctuating salinity and hydrological characteristics may be affecting the study site ecosystem, which lies midway between freshwater and saline environments. Saline-tolerant benthic species numbers will typically increase with fresh water and decrease in brackish water, and then increase again as salinity rises (Montagna and Kalke, 1992), whereas less tolerant organisms will often increase with fresher water inflow.

Salinities reached a high of 17.3 ppt in April of 1996. This high salinity possibly impacted the April sample densities, since samples from the experimental plots (plots 8, 10, 12) remained in the usual sequential order rank in March 1996 (12.4 ppt) following bioremediation treatments, with plot 8 density less than plot 10, and plot 10 less than plot 12. Densities again declined in April (17.3 ppt), except for plot 8, and the usual ranked order of density changed (plot 12 $<$ 10 $<$ 8). In July 1996,

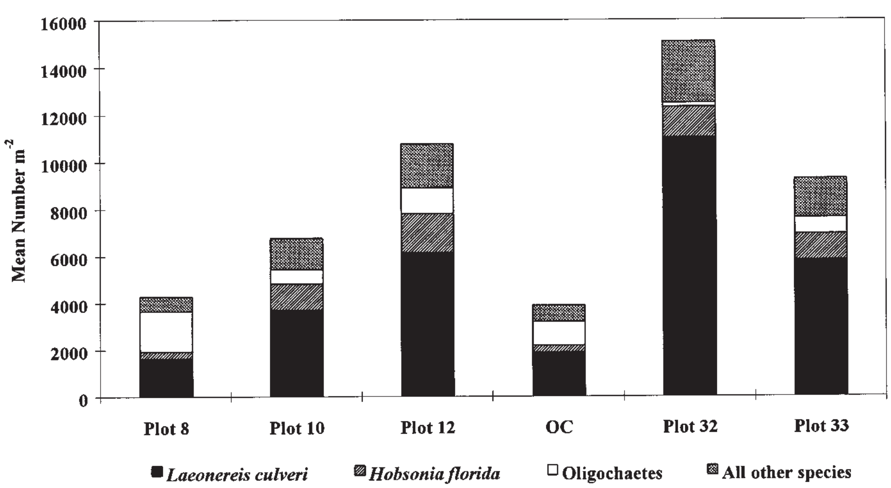

Figure 5. Mean monthly density by plot of dominant benthic species, November 1995 through April 1996 and including July 1996

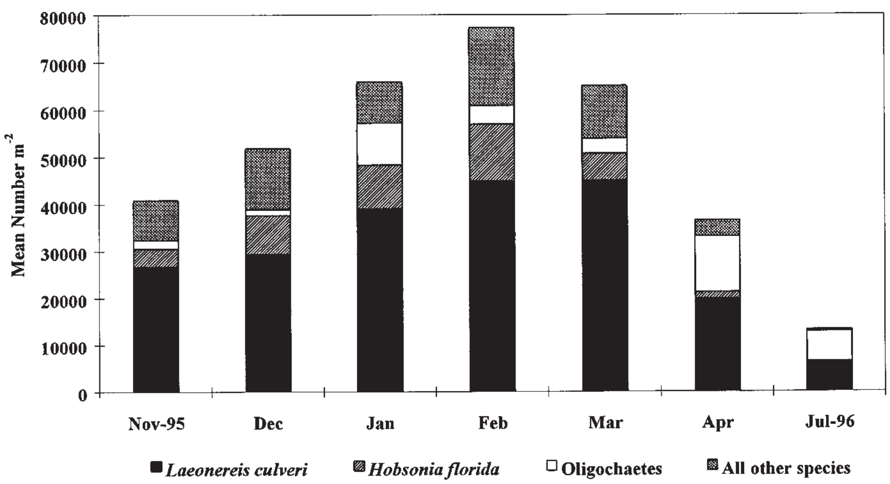

Figure 6. Mean monthly density of dominant benthic species, November 1995 through April 1996 and including July 1996

when salinity dropped to 7.8 ppt, the densities returned again to the usual order of plot 8 < 10 < 12. Plot 8 elevation is slightly higher than that of plot 10 and plot 12, and so the benthic mean monthly density could have been less impacted by higher salinity.

There was a decrease in mean monthly densities in March following bioremediation treatments; however, the average of the untreated control plots (PCC) within Parker's Cove also declined. These results may indicate a strong possibility that another factor, such as high salinity, was affecting the entire cove and impacting the control mean monthly densities. Along with the decline in mean monthly densities from March to April 1996, species richness also declined. The number of species per block had remained constant in benthic samples from February 1996 to March, further enhancing the possibility that the April 1996 rise in salinity caused declines rather than that bioremediation treatments caused the declines. The lack of May and June 1996 analyzed samples prevents one from conclusively stating that a rise in salinity is the most probable explanation for the April 1996 declines in densities and species richness.

Comparison of July 1996 benthic samples to the July 1995 baseline study (Wood *et al.*, 1995) showed that the species richness and densities improved for the plots presented here, indicating a generally improved ecological community health. Comparison of the plots in block 3 (plots 8, 10, 12) presented here and the sampled blocks (3, PCC, OC) showed that the relative order of species richness and abundance was the same in both July 1995 and July 1996 samples, indicating no differences in the improvement of treated and control plots.

July 1995 baseline samples and these 1996 benthic samples yielded different numbers of species encountered, with 17 for the former and 16 for the latter; yet the 1995 study encompassed 25 benthic sample sites, and the data for July 1996 are from 6 benthic sample sites. *Laeonereis culveri* was the dominant species from both July 1995 and July 1996. However, there were 147 individual *L. culveri* collected from 25 sample sites in 1995, accounting for 73% of the total benthic organisms collected, and in July 1996 there were 74 individual *L. culveri* collected from the 6 sample sites included in this study, accounting for only 36% of the benthic organisms collected. The lower proportion of the dominant species indicates a slightly healthier ecosystem, just 4 months after the bioremediation test oiling and continual application of additional nutrients and oxidants.

Overall biomass increased from February to March 1996, and then increased again in April. The PCC biomass increased from February to March but declined in April, while block 3 biomass decreased from February to March and increased from March to April. Although possible impact from treatments could be a factor in the change in biomass of PCC and block 3, it is also likely that the location of the plots on opposite shorelines and predation on smaller organisms led to the change in biomass from month to month.

This is an area under environmental stress, where only the most adaptable species will survive and persist. Another study indicated notable changes in freshwater benthic community populations following an 1986 lake oil spill. In more heavily oiled areas of the spill, opportunistic annelids replaced the formerly dominant insect species, and crustaceans and mollusks were nearly nonexistent (Neff and Sauer, 1995). Increased freshwater inflows also affect benthic community populations, causing different alterations in the growth rates of marine and brackish water benthic organisms.

Ecological systems often react quickly to disturbances such as contaminants, hydrological changes, and extreme weather conditions. Sensitive southern coastal wetland ecosystems repeatedly undergo hydrological, tidal, nutrient, and meteorological stress. These factors must be considered when drawing conclusions regarding field testing and the effect of bioremediation on ecological community structure. Changes in benthic species richness, density, and diversity indicate disturbances and normal seasonal trends.

The dominant benthic species, *Laeonereis culveri*, is an extremely adaptable organism that survives well in environmental conditions that other species cannot tolerate. *L. culveri* typically inhabits warm, brackish, and freshwater habitats and is cited as an important food source for shore birds (Pettibone, 1971). This polychaete is a burrowing, nonselective deposit feeder that tends to occur in the greatest abundance in the upper 10 cm of soft, fine sediments. Resistant to periods of low salinity and prolonged drought, it seems to tolerate the conditions found at Parker's Cove. Although not generally noted as an indicator of stressful environmental conditions, this polychaete is able to survive and reproduce within a highly impacted area. If this organism is ingesting the contaminated sediments of Parker's Cove, then further investigation may be warranted to learn more about the physiology and ecology of this polychaete because of its ability to survive and reproduce in this oil impacted area and its possible use as a bioremediator.

Hobsonia florida, a polychaete representing the second most dominant species identified in this study, and *Rangia cuneata*, the dominant bivalve (limited numbers were collected in samples, but large numbers were observed throughout the site), are less saline-tolerant; and species distribution is generally restricted to a limited salinity range in Texas bay waters. Although species such as *H. florida* and *R. cuneata* often experience rapid population growth after increases in freshwater inflow, extreme or long-term inflow of fresh water may adversely affect populations (Longley, 1994). *H. florida* increased in abundance from November 1995 until it reached a high of 190 in February 1996, declining to a low of 22 individual organisms collected in April 1996 for the 6-month sampling period. Since *H. florida* is not tolerant of high salinities, this further emphasizes the possibility of lower benthic densities and species richness being affected by salinity rather than bioremediation treatments.

Although there were no statistically significant differences in benthic community structure between blocks or between plots, there were indications of statistical differences between months. Comparisons between mean densities of plots do indicate some unusual patterns. When compared to the reference control (30), all plots had higher mean species density, yet when compared to the cove control site (32), all plots experienced lower mean species density (see Figure 5). Therefore, although initial comparisons and analysis have offered other possible causes for reduced numbers, conclusions cannot be substantiated at this time because of the limited data set available. In addition, with only a preliminary data set completed, and with many variables affecting ecological community structure, a conclusive assessment of bioremediation treatment effects upon an ecosystem is difficult to make.

The sampling process places stress on the ecological community; it is essential to eliminate this stress when delineating between the impacts of oil, bioremediation, and humans. Additional disturbance from sampling within the sensitive wetland study sites and shorelines should be kept to an absolute minimum. Interdisciplinary analysis of the entire data set must be completed to verify conclusions regarding differences in the effects of bioremediation treatment.

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Biography

Terri Wood is a graduate student with the Center for Coastal Studies at Texas A&M University. Her research encompasses both field and laboratory studies of coastal wetlands.

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