Oilfield Produced Water

An Assessment of Produced Water Impacts in the Galveston Bay System: Preliminary Findings

R. Will Roach
U.S. Fish and Wildlife Service

Produced water (or oil field brine) is a by-product associated with oil and gas recovery operations. Common methods of brine disposal include deep-well injection, whereby the water is injected back into the petroleum formations from which it was withdrawn, and discharge to surface waters, commonly known as "tidal disposal" because of its restriction to tidally-influenced waters within the state. Texas Railroad Commission (RRC) 1990 estimates indicate that the Galveston Bay system and its tributaries receive more than 326,000 barrels (13.7 million gallons) of produced waters per day from 76 permitted sources. Fifty-seven percent of the discharges (by volume) went to bayou systems; shoreline and open-bay discharges accounted for 35 and eight percent, respectively. The actual volumes discharged into the bay vary greatly, depending upon the economic feasibility of oil production and the length of reservoir production (i.e., older fields yield proportionally more water).

Produced waters typically contain high levels of dissolved solids, ranging in salinity from 12 to 160 parts per thousand; metals concentrations much higher than those of receiving waters; and up to 25 parts per million oil and grease. Radioactive isotopes are also prevalent in produced waters. Concentrations of radium 226 in brines often exceed regulatory criteria established for other industries. The RRC issues tidal disposal permits, provided that the discharge meets applicable Texas Surface Water Quality Standards. EPA does not currently regulate these discharges under its National Pollutant Discharge Elimination System.

Recent studies of the effects of brine upon estuarine systems have shown that high levels of dissolved solids allow the formation of a density gradient, especially in low energy systems such as bayous; oil and chlorides are incorporated into sediments near discharges, severely depressing the abundance and richness of benthic infauna; elevated salinities inhibit nekton movement; and petroleum hydrocarbons are ingested and incorporated into the tissues of various aquatic organisms. King (USFWS, unpublished data) found that migrant shorebirds accumulated polynuclear aromatic hydrocarbons 24-fold while wintering in the vicinity of produced water discharges.

The objective of this study is to provide a general assessment of any adverse environmental effects resulting from the "tidal disposal" of produced waters at two sites. The Tabbs Bay site (a shoreline discharge) and the Cow Bayou site were the primary study sites selected for characterization within the Galveston Bay system (Fig. 1). Three transects were established radiating from the discharge into Tabbs Bay. A reference site was located approximately four miles away in upper Galveston Bay. Three stations in Cow Bayou, two stations in Robinson Bayou (a reference bayou influenced by urban runoff) and two stations in Clear Creek were selected to assess impacts upon bayou habitats.

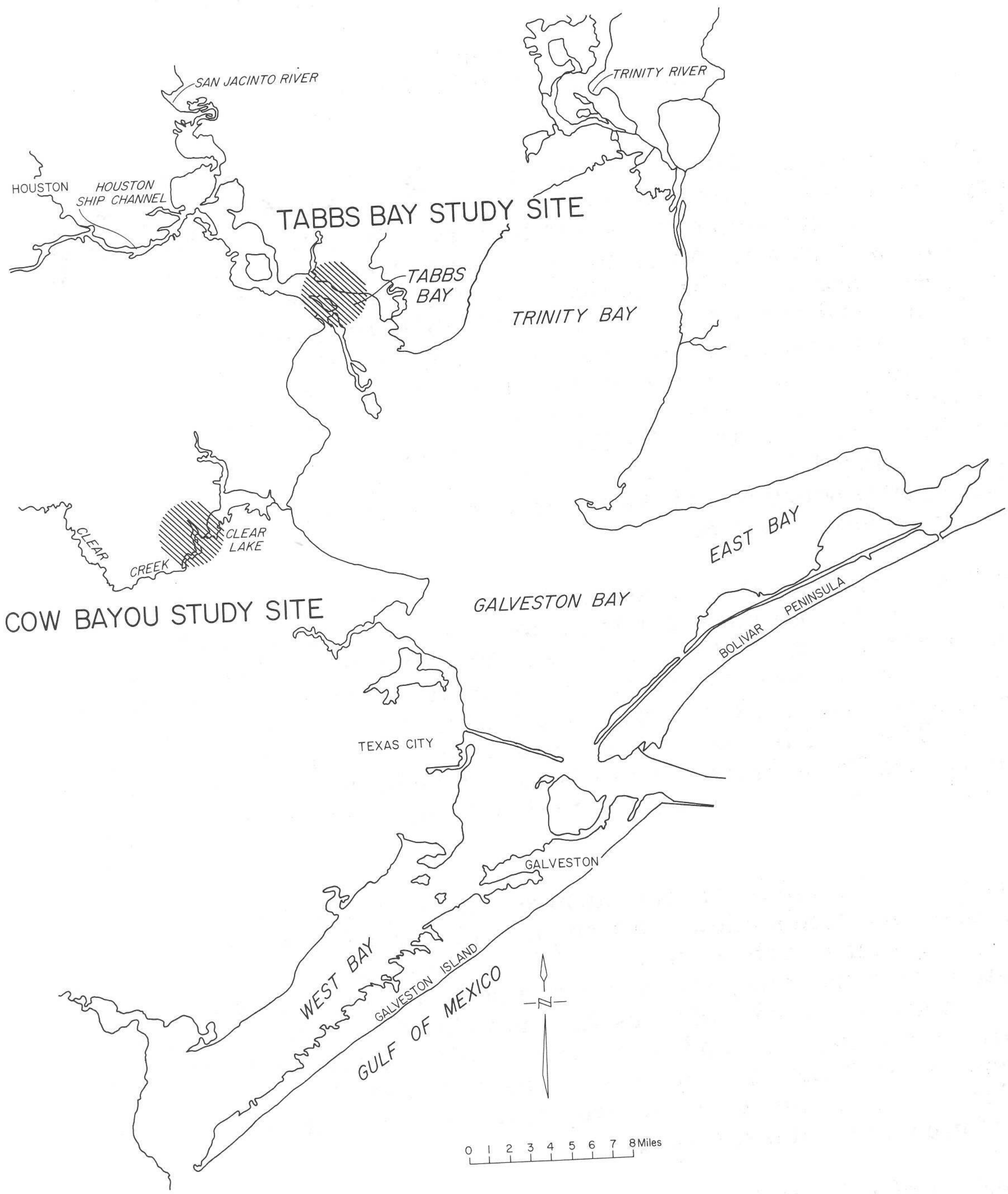

Figure 1. Location of Cow Bayou and Tabbs Bay study sites.

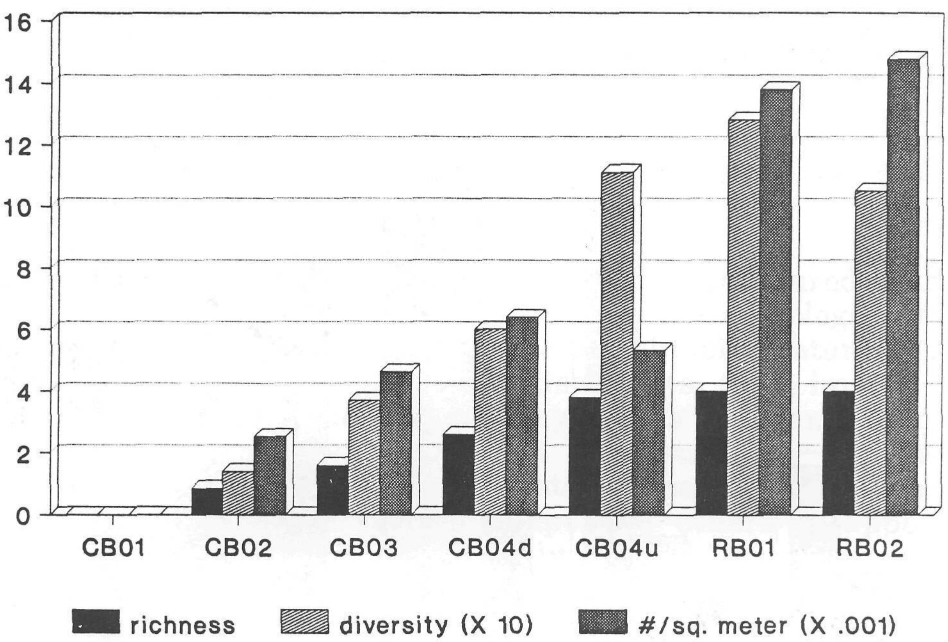

Figure 2. Richness, diversity, and abundance of benthos at the Cow Bayou study site.

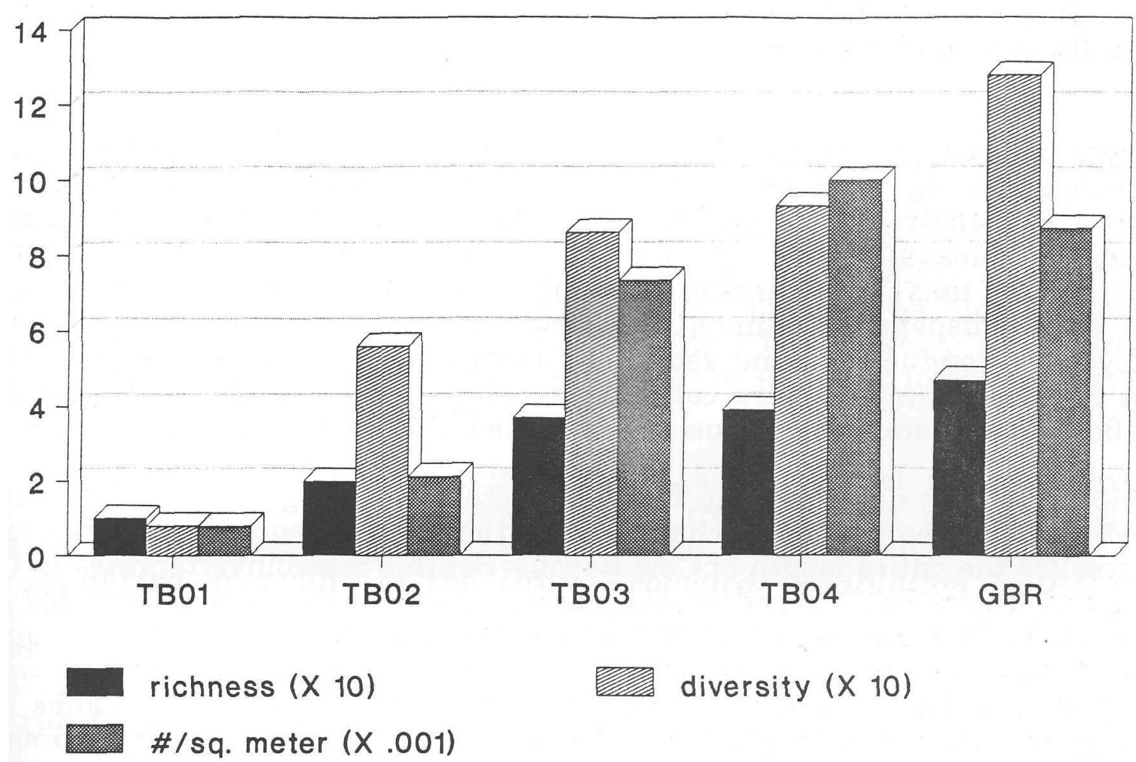

Figure 3. Richness, diversity, and abundance of benthos at the Tabbs Bay study site.

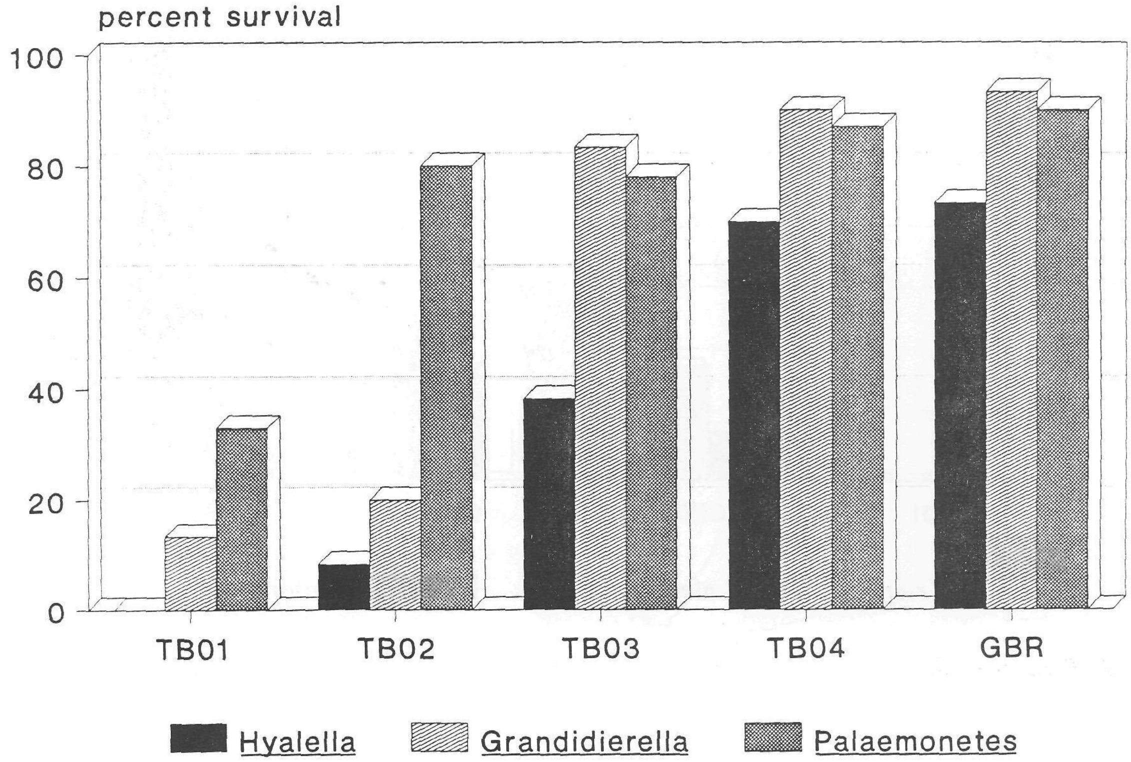

Figure 4. Percent survival of organisms exposed to Tabbs Bay sediments (S. Burch, R. S. Carr, and C. L. Howard, unpublished data).

Sediment, effluent, water and tissue samples were collected for residue analyses of organic and inorganic constituents. Acid volatile sulfides, total organic carbon, and grain size analyses were performed on sediment samples to provide indices of contaminant bioavailability. A suite of bioassays was conducted using pore waters, surface microlayer samples, and effluents from the Tabbs Bay site. Solid-phase and resuspended sediment bioassays for acute, chronic, and sublethal toxicity were conducted using sediments from selected stations at both sites. Seven replicate samples were collected at each station for macroinvertebrate identification and enumeration using a modified Mackin 2-inch coring device.

Benthic community data from the Tabbs Bay site indicate significant effect only at the two stations nearest the discharge, while the infaunal populations are absent or sparse for the entire length of Cow Bayou. Benthic macroinvertebrates in Cow Bayou and Tabbs Bay ranged in abundance, respectively, from 0 and 787 per square meter at stations nearest the discharge to 14,760 and 9,988 per square meter at distant or reference stations (Figs. 2 and 3). Sediment and pore-water toxicity data indicate significant impact within 370 meters of the Tabbs Bay discharge and the entire length of Cow Bayou (Fig. 4). Sediment samples from all stations were analyzed for organic and inorganic constituents. Results indicate that bayous receiving brines are more adversely inpacted than are shallow bay habitats.

Stress Proteins as Bioindicators of Exposure to Brine-Contaminated Sediments from Galveston Bay

Cynthia L. Howard
School of Natural and Applied Sciences, University of Houston - Clear Lake

Contaminant levels in estuarine sediments have been measured with precision for quite some time, but only recently have any associated biological effects been studied. There is now growing interest in the use of bioindicators as monitoring tools in the management of pollutant discharges that impact estuarine sediments. Sediment contaminated with heavy metals or organic compounds can affect invertebrate and fish populations at concentrations too low to cause significant mortality in traditional toxicity tests, but can still influence estuarine community structure as some species adapt and others disappear. These sublethal effects can be detected using carefully selected bioindicators, such as the presence or absence of "indicator species," changes in growth rates, fecundity or viability of young, or the induction of specific biomolecules (stress proteins) involved in detoxification or compensatory responses.

A significant amount of contamination of sediments in the Galveston Bay estuarine system can be attributed to waste discharges of oil field produced water (brine) from active oil and gas wells. Produced water is typically hypersaline and contains high concentrations of heavy metals and water soluble fractions of oil. These compounds become incorporated into the sediments around the discharge sites, depress benthic species diversity and accumulate in the tissues of tolerant organisms. Organisms that inhabit these areas most likely have adapted biochemically and physiologically to the chemical stresses.

The objective of this study is to evaluate two different approaches to monitoring the biological effects of brine-contaminated sediment collected from impacted areas in Tabbs Bay and Cow Bayou, using: (1) the traditional resuspended sediment and whole sediment benthic bioassays; and (2) stress proteins as bioindicators of sublethal toxicity. The long-term goal of the study is to develop stress protein analysis as a reliable bioindicator for monitoring the sublethal impact of chemical pollutants on estuarine communities.

Sediment was collected from a reference site and four test stations along a transect at the Tabbs Bay discharge site and from two test stations and two reference sites downstream from the Cow Bayou discharge site. Toxicity tests were conducted according to the *Draft Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters* (EPA-503-8-90/002, 1990) procedures for Tier III bioassays (96-hour resuspended sediment and 10-day benthic tests) using grass shrimp (*Palaemonetes pugio*). Additional replicates were run to include cadmium exposures as a positive control on stress protein accumulation. Survivors of both tests were frozen at -70° C. There was no significant mortality resulting from exposure to resuspended sediment among any of the sediment groups. In the benthic bioassays, sediment from the two stations nearest the Tabbs Bay outfall produced 30% and 20% mortality, respectively.

Grass shrimp from each sediment-cadmium exposure group were pooled, homogenized and centrifuged to obtain a 10,000 x g supernatant. Stress proteins ranging in molecular weight from 12 to 150 kilodaltons (kd) were identified by gel electrophoresis and quantified by scanning densitometry. At least two proteins were induced when grass shrimp were exposed to brine-contaminated sediment. A 55 kd stress protein was accumulated in shrimp exposed to resuspended or whole sediment from the brine-contaminated stations and in shrimp exposed to cadmium in any of the sediment groups. This protein was present, but at reduced levels, in shrimp from the control sediment and no sediment groups. A 80 kd stress protein was also accumulated by shrimp exposed to brine-contaminated sediment.

The resuspended sediment and benthic bioassay methods used in this study produced results indicating no significant toxicity of the brine-contaminated sediments, yet grass shrimp exposed to sediment from the stations nearest the two produced water outfalls responded definitely by accumulating stress proteins. What effects these sublethal biochemical changes cause at the population or community level are presently unknown. However, since actual species richness and diversity at these stations is zero or very low compared to control stations, one cannot conclude that these sediments are not toxic.

Characterizing the mechanisms of pollution response has ecological and management significance for at least two reasons. First, benthic invertebrate species constitute an integral part of the estuarine food web that supports large populations of sport and commercial fish and shellfish. Adaptation to chemical pollution may lead to changes in the abundance of preferred food species relative to non-food species, which could exert long-term effects on predatory fish populations. Adaptation may also lead to tolerance for high tissue concentrations of toxicants, thereby increasing the load in estuarine biota through bioaccumulation or biomagnification. Second, because many benthic and epibenthic estuarine invertebrates are restricted to a relatively small area throughout their lives, they may provide excellent bioindicators for monitoring sediment contamination in a bay management program.