

Surveys for Toxicants

Survey of Galveston Bay Bottom Sediments and Benthic Communities

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The purpose of this study was to characterize the quality of sediments at key sites in the Galveston Bay Estuary (Table 1, Fig. 1). Synoptically collected sediment samples were taken for chemical and physical analyses, toxicity testing, and an assessment of benthic community structure in order to identify areas where sediment contamination is responsible for ecosystem degradation (Chapman, 1990). The chemical analyses included a suite of trace metals, petroleum aromatic hydrocarbons (PAHs), chlorinated hydrocarbons, total organic carbon (TOC), and acid volatile sulfides (AVS), in order to normalize the organic and inorganic constituents, respectively. Solid-phase sediment toxicity tests with the benthic amphipod *Grandidierella japonica* were conducted (ASTM, 1990). In addition, the U.S. Fish and Wildlife Service (USFWS) conducted a series of sediment porewater tests with gametes of the sea urchin, *Arbacia punctulata* (Carr and Chapman, 1992).

Significant toxicity, as determined by the sea urchin porewater morphological development assay, was observed at 12 of the 24 sites investigated in this study (Fig. 2). The solid-phase amphipod test, which is not particularly sensitive to environmental degradation, showed no toxicity at any of the sites. There were a number of sites with elevated levels of trace metals and petroleum hydrocarbons (Table 2). Species richness and abundance data were suggestive of environmental degradation at a number of sites (Figs. 3 and 4). The chemistry, toxicity, and benthic data were ranked by station and a rank sum was calculated to facilitate comparisons among the sites (Table 3).

All of the sites adjacent to dredged material disposal islands and produced water separator platforms appeared to be environmentally degraded. A number of other sites also exhibited sediment toxicity or elevated concentrations of trace metals. Sediment toxicity without obvious elevated levels of contaminants or altered benthic communities indicates the potential for environmental degradation (e.g., Smith Point), or the toxic contaminants may not have been included (or occur at such low levels that they were not detected) in the chemical analyses. Sites with elevated levels of contaminants but no toxicity indicate that the contaminants are not bioavailable (e.g., Swan Lake).

Table 1. *Sampling sites for Galveston Bay Bottom Study.*

Site #	Site Description	Reason for Selection
1B ¹	Morgan Point, GERG station A, between BEG stations #353 and #351	Contaminant body burden data available from GERG study and sediment chemical data available from BEG study
2B	Jack's Pocket, Houston Light & Power (HL&P) Trinity Bay Station, (the most southeasterly station on HL&P transect G closest to the Bureau of Economic Geology (BEG) station #462)	Excellent historical data base exists for benthic community structure and sediment chemical data available from Houston Lighting & Power (1980) and Bureau of Economic Geology (1985) studies
3B	Eagle Point, GERG station B, BEG station #104	Contaminant body burden data available from GERG study and sediment chemical data available from BEG study
4B	South of Hannas Reef in East Bay, NOAA study station #17, near TWC site SMN #2439.0150, BEG station #116, and GERG station C, 500 m S.W. of tide gauge	Historical information for sediment organic and inorganic chemistry from NOAA study, benthic community structure information from TWC and BEG studies, and contaminant body burden data from GERG study
5B	West of Carancahua Reef in West Bay, BEG station #46, GERG station D	Benthic community structure data available from BEG study and contaminant body burden data from GERG study
6	Burnett Bay, near BEG station #13	Historical information on metals and benthic community structure data from BEG study available
7	Cedar Bayou, 0.25 mi due west of BEG station #390	High sediment chromium concentrations observed in BEG study
8	Umbrella Point, BEG station #358 located near Schropp's station #8	Historical data for chemical and benthic analysis from HL&P, BEG, and Schropp (1979) Sun Oil Co. studies
9	100 m due south of Fishers Reef C-2 separator platform in Trinity Bay, near BEG station #401	Benthic and chemical data available from Armstrong et al. (1979) and BEG studies
10	North of Smith Point, BEG station #265	High sediment copper and lead concentrations observed in BEG study
11	South of Lake Surprise in East Bay, 0.23 mi due west of BEG station #200	High sediment strontium concentrations observed in BEG study
12	0.5 mi north of March Point in East Bay, BEG station #208	Depositional zone representative of eastern portion of East Bay; metals and benthic community structure information available for nearby BEG stations
13	Kemah Flats, ~250 m due west of channel marker #2, BEG station #249	Adjacent to non-point source urban runoff from Clear Lake area; benthic community structure information available from BEG study
14	Southeast of Texas City, BEG station #8	Depositional zone adjacent to non-point source urban and industrial runoff; benthic community structure and metals data available from nearby BEG stations
15	Jones Bay, 0.55 mi north of BEG station #13	Historical information on metals and benthic community structure for nearby BEG stations available
16	Chocolate Bay, 0.04 mi north of BEG station #72	Historical information on metals and benthic community structure available from BEG study

Site #	Site Description	Reason for Selection
1S ²	~100 m Southwest of Alexander Island, near BEG station #7	Adjacent to a confined dredged material disposal area
2S	Black Duck Bay	Adjacent to industrial treatment lagoons
3S	~200 m north of Lost Lake Island	Adjacent to a confined dredged material disposal area
4S	Southeast side of Atkinson Island, near BEG station #342	Adjacent to a semi-confined dredged material disposal area
5S	~100 m south of F-2 produced water separator platform	Adjacent to an active produced water separator platform
6S	~150 m south of F-1 produced water separator platform	Adjacent to a produced water separator platform
7S	Swan Lake	Adjacent to non-point source urban and industrial runoff
8S	Dollar Bay	Adjacent to non-point source urban and industrial runoff

Site #	Site Description	Reason for Selection
1S2	~100 m Southwest of Alexander Island, near BEG station #7	Adjacent to a confined dredged material disposal area
2S	Black Duck Bay	Adjacent to industrial treatment lagoons
3S	~200 m north of Lost Lake Island	Adjacent to a confined dredged material disposal area
4S	Southeast side of Atkinson Island, near BEG station #342	Adjacent to a semi-confined dredged material disposal area
5S	~100 m south of F-2 produced water separator platform	Adjacent to an active produced water separator platform
6S	~150 m south of F-1 produced water separator platform	Adjacent to a produced water separator platform
7S	Swan Lake	Adjacent to non-point source urban and industrial runoff
8S	Dollar Bay	Adjacent to non-point source urban and industrial runoff

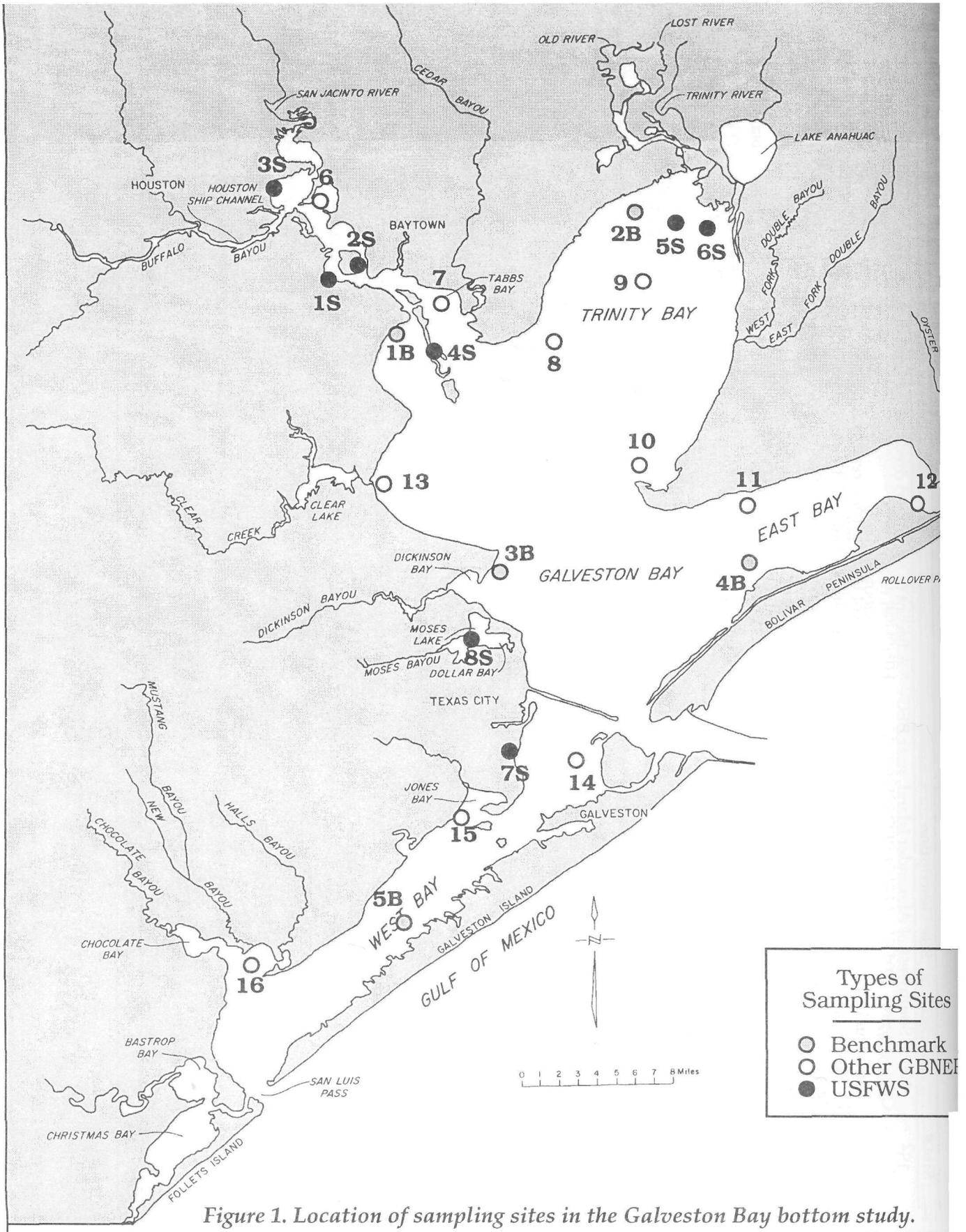


Figure 1. Location of sampling sites in the Galveston Bay bottom study.

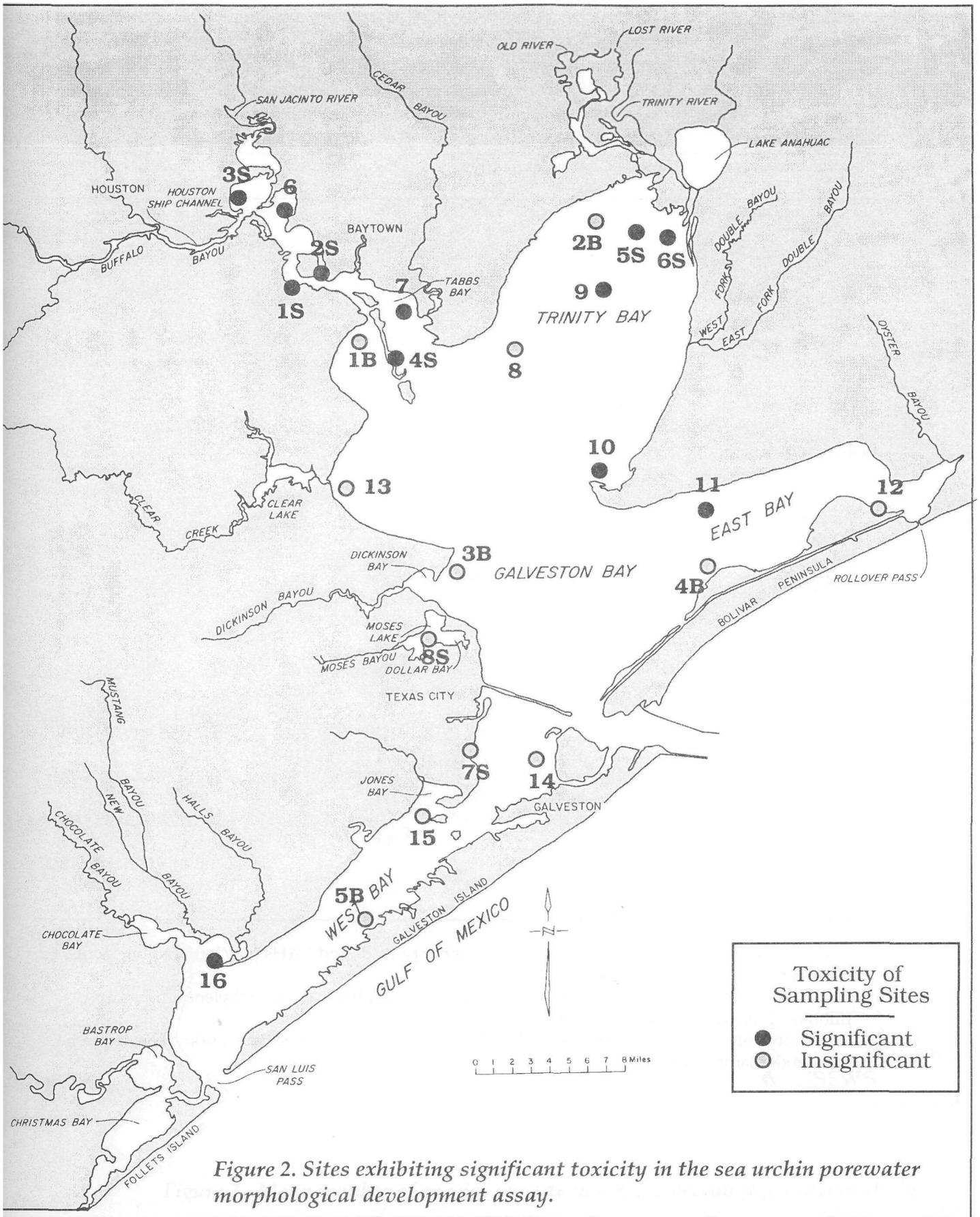


Table 2. *No-Observed-effect level (NOEL), probable effects level (PEL; MacDonald, 1992), effects range low and median (ER-L and ER-M, respectively; Long and Morgan, 1990), and the apparent effects threshold (AET; Tetra Tech, 1986) values for key contaminants and stations exceeding those values.*

Contaminant	NOEL	PEL	ER-L	ER-M	AET	Station Exceeding NOEL or ER-L ¹
PCBs (µg/kg)	24	260	50	400	50	2S (50)
Polycyclic Aromatic Hydrocarbons (µg/kg)						
Acenaphthene	22	450	150	650	56	5S (70)
Acenaphthylene	<35	500	-	-	44	7S (51)
Anthracene	85	740	960	960	13,000	-
Fluorene	19	460	35	640	3600	-
Naphthalene	130	1100	340	2100	160	5S (54)
Phenanthrene	140	1200	225	1380	170	9 (250)
ΣLMW PAHs ²	250	2400	-	-	2100	5S (252), 9 (278)
Benz(a)anthracene	160	1300	230	1600	5100	9 (341)
Benzo(a)pyrene	230	1700	400	2500	-	-
Chrysene	220	1700	400	2800	190	9 (288)
Dibenzo(a,h)-anthracene	31	320	60	260	1200	9 (32)
Fluoranthene	380	3200	600	3600	390	9 (706)
Pyrene	290	1900	350	2200	16,000	9 (2152)
Trace Elements (mg/kg)						
As	8	64	33	85	64	7S (9)
Cd	1	7.5	5	9	7.5	-
Cr	33	240	80	145	2600	6 (63), 7 (40), 11 (37), 2S (41), 5S (40), 7S (82)
Cu	28	170	70	390	310	-
Pb	21	160	35	110	150	4B-2 (26), 5B-3 (22), 6 (35), 2S (23), 7S (147)
Hg	0.1	1.4	0.15	1.3	1.3	6 (0.3), 2S (.13) 3S (.14)
Ni	-	-	30	50	>140	-
Zn	68	300	120	270	340	4B-1 (70), 4B-2(125), 4B-3 (70), 6 (158), 7 (75), 9 (81), 11 (82), 5S (78) 7S (165)

¹ Concentrations in parentheses. Units for contaminants: PCBs and PAHs (µg/kg), trace elements (mg/kg)

² Sum of the following low molecular weight PAHs; acenaphthene, acenaphthylene, anthracene, fluorene, 2-methylnaphthalene, naphthalene and phenanthrene

³ Sum of the following high molecular weight PAHs; benz(a) anthracene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene and pyrene

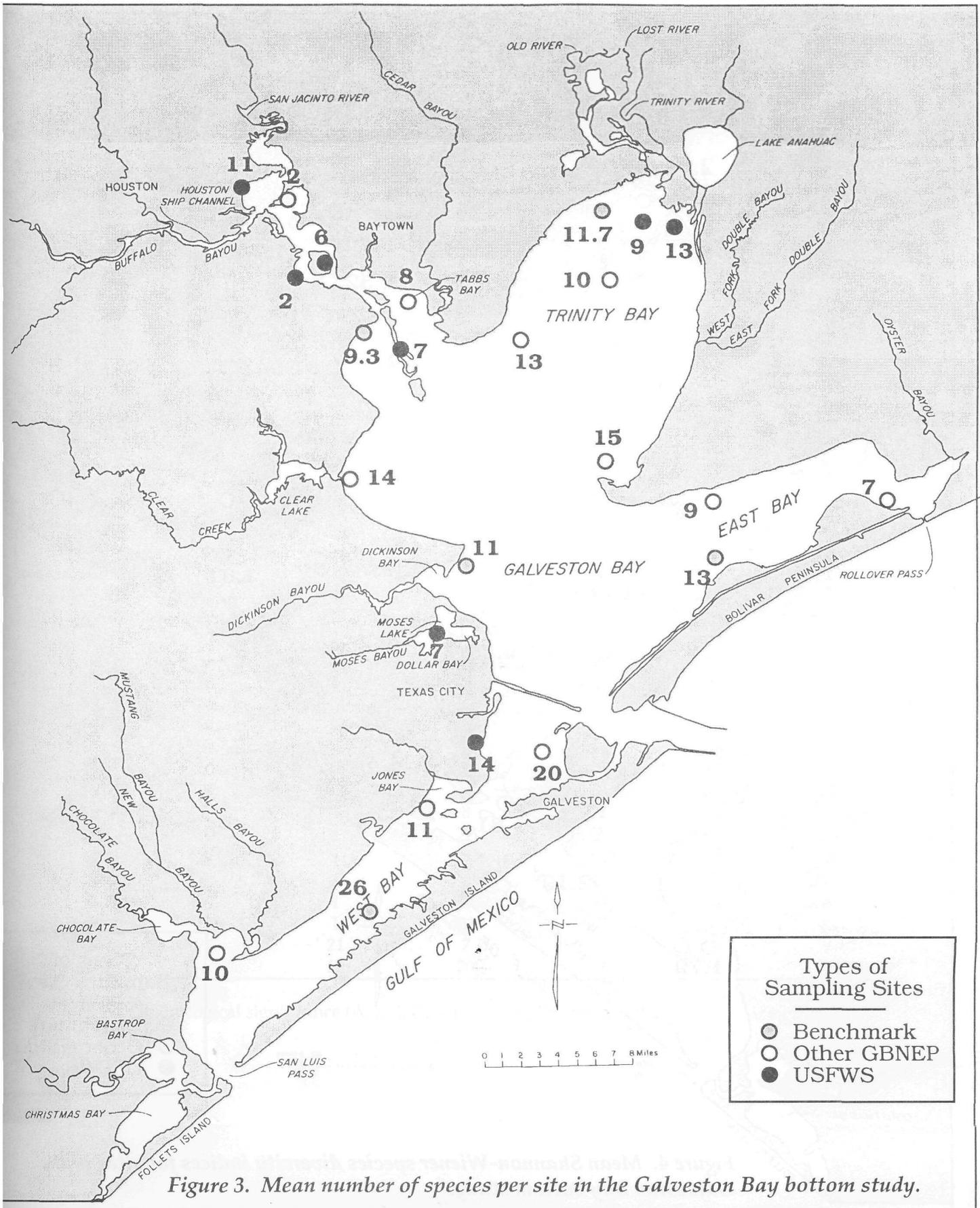


Figure 3. Mean number of species per site in the Galveston Bay bottom study.

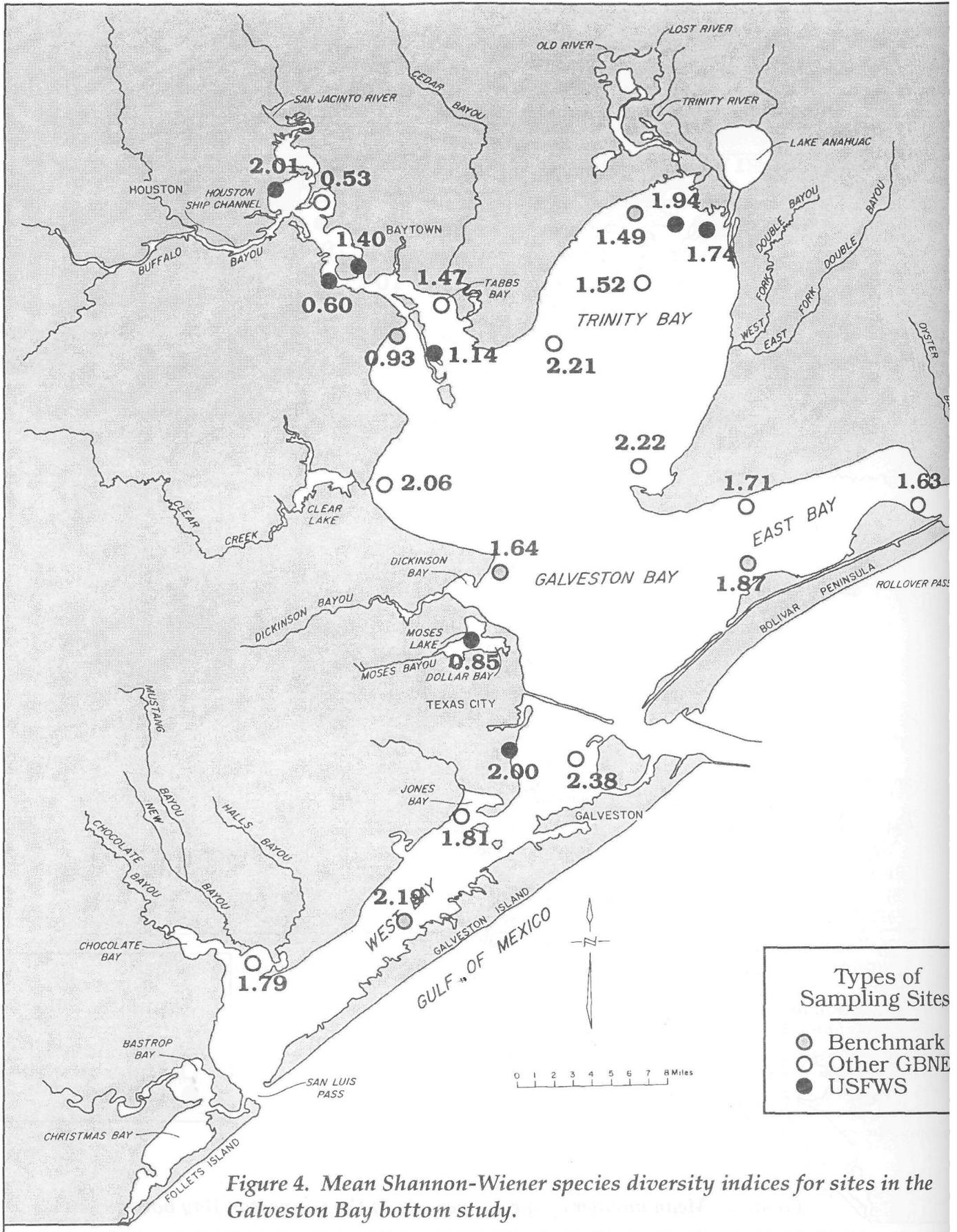


Figure 4. Mean Shannon-Wiener species diversity indices for sites in the Galveston Bay bottom study.

Table 3. Station ranks and rank sum of benthic invertebrate species diversity (shannon-Wiener), toxicity (sea urchin morphological development), TOC normalized PAHs and bulk sediment metal concentrations for Galveston Bay Bottom Study. the higher the ranking the less degraded the station relative to the other stations.

Station	Rank				Rank Sum	Relative Rank
	Benthic Diversity	Toxicity	PAHs	Metals ¹		
1B-1	5	21	10	27	63	13
1B-2	8	26	11	29	74	22
1B-3	3	24	6	24	57	10
2B-1	9	26	12	34	81	27
2B-2	15	26	15	28	84	28
2B-3	13	21	2	31	67	17
3B-1	22	24	1	33	80	25
3B-2	7	20	9	30	66	16
3B-3	18	16	5	32	71	21
4B-1	23	31	27	9	90	30
4B-2	21	31	28	4	84	28
4B-3	24	33	31	10	98	31
5B-1	33	29	32	26	120	34
5B-2	21	33	34	23	111	32
5B-3	32	29	33	20	114	33
6	1	1	24	3	29	2
7	11	1	29	7	48	7
8	30	15	22	12	79	23
9	12	1	3	6	22	1
10	31	1	16	17	65	15
11	16	1	30	5	52	8
12	14	14	23	16	67	17
13	29	13	26	11	79	23
14	34	18	14	14	80	25
15	20	18	14	15	67	17
16	19	12	18	19	68	20
1S	2	1	8	22	33	3
2S	10	1	25	2	38	4
3S	28	1	19	13	61	12
4S	6	1	17	21	45	6
5S	25	1	4	8	38	4
6S	17	1	21	25	64	14
7S	27	21	7	1	56	9
8S	4	17	20	17	58	11

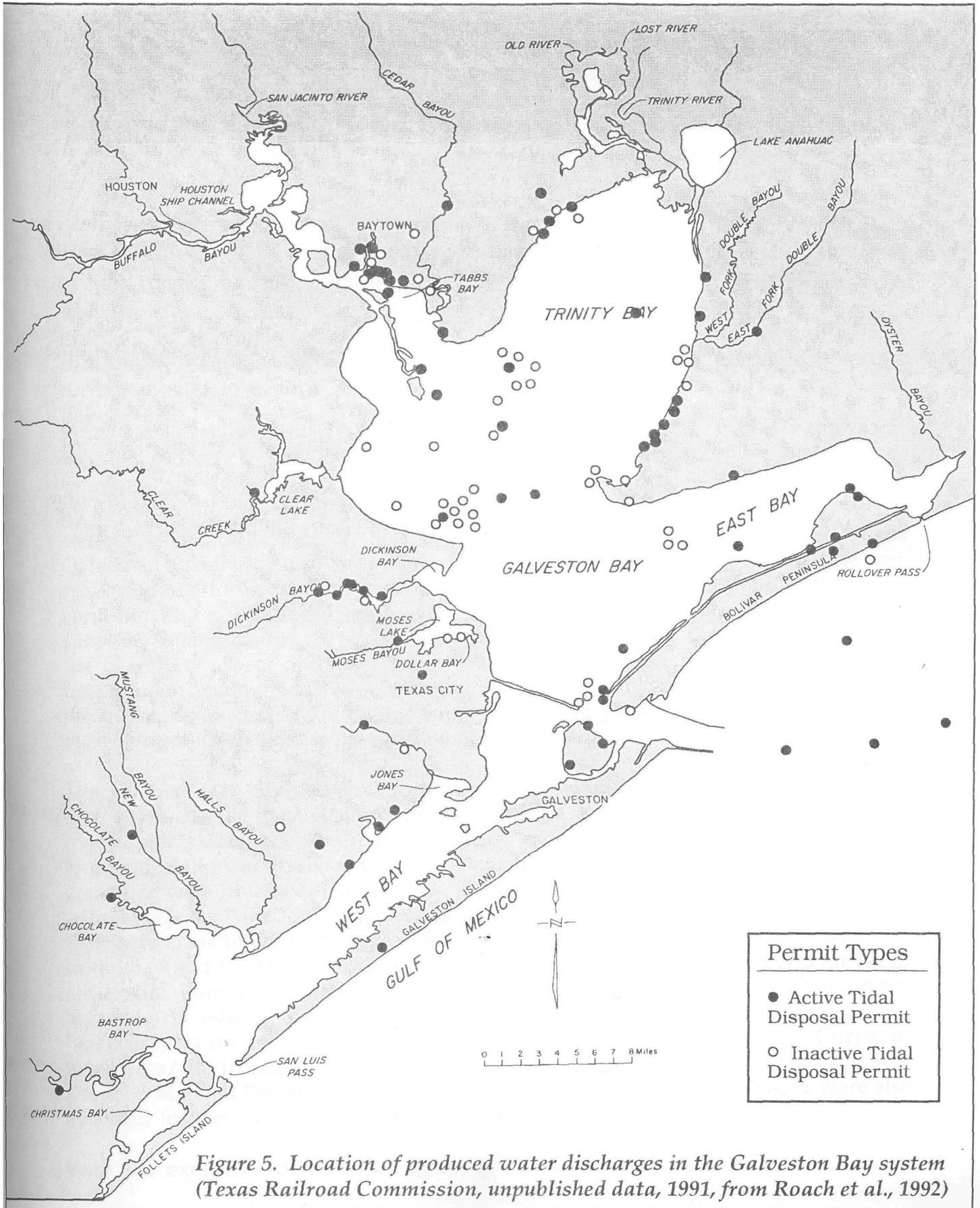
¹ Metals of toxicological significance (As,Cd, Cr, Cu, Hg, Ni, Pb, and Zn)

While the overall "health" of the Galveston Bay complex appears to be acceptable for the majority of the system, there are obvious areas that have been impacted by petrochemical and dredging activities. Sites sampled in the upper Houston ship channel were all highly degraded. Sites adjacent to produced water separator discharges had high PAH concentrations and were highly toxic. While the impact of these discharges decreases with distance from the outfall, it appears that the impact of chronic produced water discharges in shallow estuaries, such as Trinity Bay, is evident for some time after the discharge is discontinued with a pronounced accumulation of the more refractory high molecular weight PAHs remaining.

This broad scale survey has identified a number of potential problem areas within the Galveston Bay system. The source of deleterious contamination was evident at some sites and unknown at others. Past and present petroleum exploration and production activities, for example, are widespread throughout the Galveston Bay system (Fig. 5). The impacts of other point and non-point source inputs is not presently known. It is apparent that inputs from some of these sources could be reduced or eliminated by alternative regulatory and management practices. Only by conducting more focused and comprehensive studies can the full degree and extent of contaminant impacts in the Galveston Bay system be ascertained.

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Contaminants Study for Houston-Galveston Navigation Channels

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As part of the proposed widening and deepening of the Houston-Galveston Navigation Channels, Texas, an Interagency Coordination Team (ICT) was formed to help determine the scope of studies necessary to evaluate project impacts. A Contaminant Subcommittee was formed to determine the studies required to evaluate contaminant issues associated with the project. The Subcommittee was comprised of representatives from the U. S. Army Corps of Engineers, Galveston; Environmental Protection Agency, Dallas; U. S. Fish and Wildlife Service, Clear Lake; Texas Parks and Wildlife Department, LaPorte; and the Texas Water Commission, Houston and Austin.

The proposed widening and deepening of the Houston Ship Channel extends from offshore in the Gulf of Mexico to Boggy Bayou in the landlocked portion of the channel, a distance of nearly 50 miles (Figure 1). Deepening of a portion of the Galveston Channel is also proposed. It was the consensus of the ICT that the new work material to be dredged from the channel enlargements was not a contaminant concern. The ICT believed the greatest contaminant potential was in the overlying shoal or "maintenance" material. Since the disposal plan for the project envisioned the beneficial use of both the new work and maintenance dredged material, the contaminant studies had two objectives: (1) evaluate the contaminant potential of the maintenance material utilizing approved testing procedures; and (2) determine the potential for beneficial uses of the maintenance material.

The channel was divided into four reaches: the Entrance Channel, the Bolivar Roads Reach, the Bay Reach, and the Upland Reach (Figure 1). The testing requirements included grain-size analysis, chemical analysis, and bioassay and bioaccumulation analysis. Along the 50 mile length, samples for chemical and grain-size were obtained. Samples were collected every 1,000 feet along the channel with every five stations composited and analyzed for the priority pollutants. Reference areas in the Gulf and in Galveston Bay were also composited for analyses. In the Bay and Upland Reaches, sediment samples were also collected and analyzed for dioxin. Samples were collected every 5,000 feet along the channel and reference areas with every five stations composited for analyses. Bioassay and bioaccumulation tests utilized the procedures as described in the Corps of Engineers/Environmental Protection Agency Testing Manual "Evaluation of Dredged Material Proposed for Ocean Disposal" (EPA/DOA, 1991). Tissues were also analyzed for the priority pollutants.

With the exception of the Bolivar Roads Reach, maintenance material from the

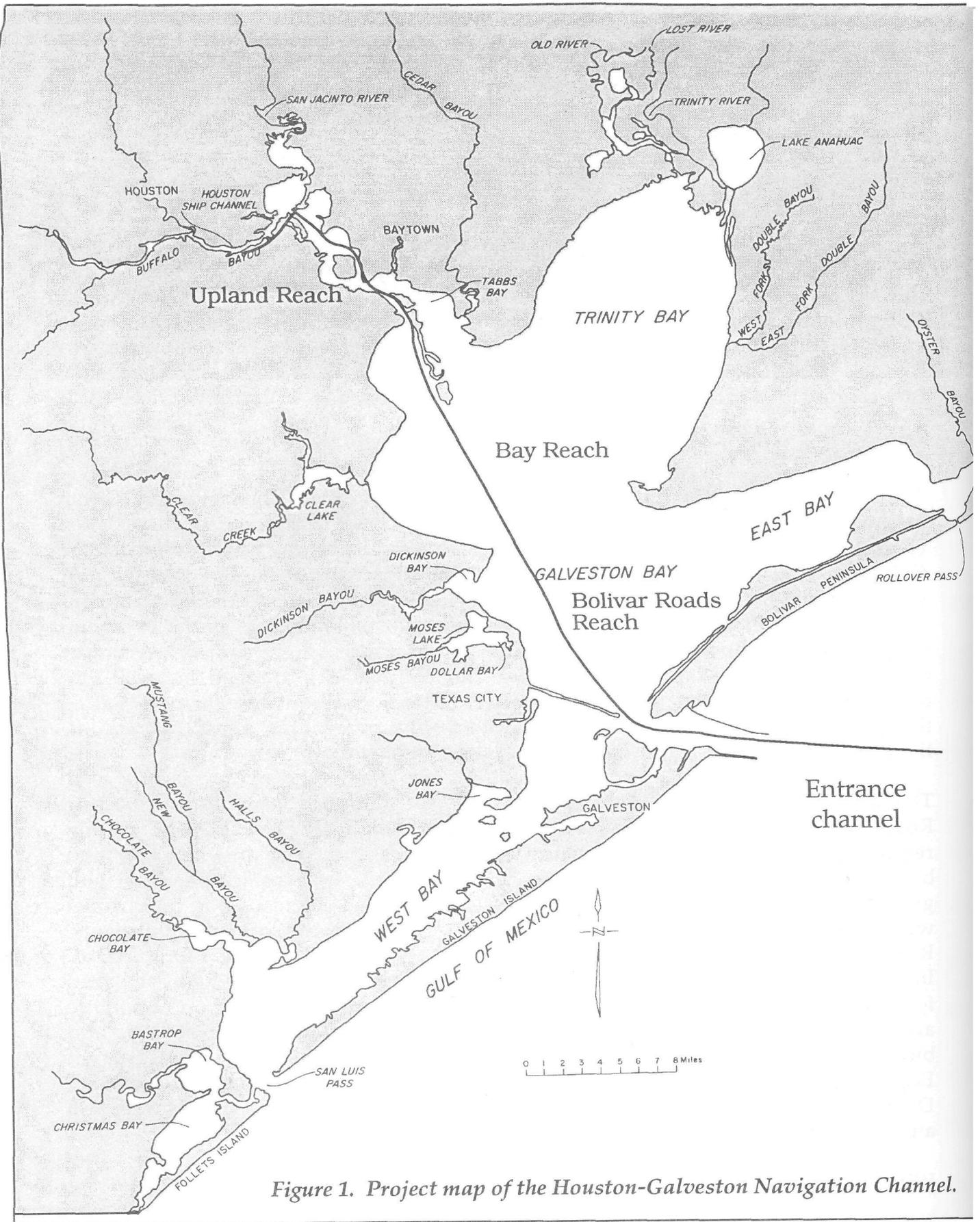


Figure 1. Project map of the Houston-Galveston Navigation Channel.

channel is predominantly fine-grained silts and clays with less than 20% of the material being classified as sand. The Bolivar Roads Reach averages over 75% sand, with some segments as high as 90% sand.

For the priority pollutants throughout the channel length, levels for metals were comparable to historical data, while organics were generally below detection levels. The composite samples were also split and sent to the U.S. Fish and Wildlife Service (USFWS) laboratory for comparative metals analyses. The USFWS results were within the same order of magnitude as the original analyses. Dioxin was detected in only one sample at a very low level. The subcommittee concluded that there were no dioxin concerns with the maintenance material.

For the Entrance Channel, the results of a 10-day sediment bioassay showed no statistically significant differences in organism survival between test and reference sediments. Tissues from organisms surviving a 28-day sediment bioassay were analyzed for bioaccumulation potential. No statistically significant differences were observed between tissue concentrations in test and reference sediments.

Given the high sand content in the Bolivar Roads Reach, the high energy area, and no indication of a contamination problem based on the sediment analyses, the testing exclusion requirements of both the Ocean Dumping Act (40 CFR 227.13(b)(1)) and the Clean Water Act (40 230.60(a)) were satisfied.

In the Bay Reach, water column bioassays were performed. The results showed that, for most tests, there were no statistically significant differences in organism survival between test and reference sediments. At one mid-bay station, however, significance was encountered, although retesting showed no significance. Results of sediment bioassays and bioaccumulation analyses showed no significant differences between test and reference sediments.

In the Upland Reach, testing is underway. An existing dredged material disposal that is in use will be monitored for effects of the discharge effluent. Based on the monitoring, management plans will be developed for using the upland disposal areas.

Based on the evaluations and results described above, the Contaminant Subcommittee concluded, and the ICT concurred, that there are no contaminant concerns related to dredging and disposal of maintenance material from the Houston-Galveston Navigation Channels project. In addition, the material is considered acceptable for beneficial uses in the ocean and the bay. Maintenance material will continue to be analyzed for priority pollutants both before and after project construction.

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Potential Toxicity Concerns for Galveston Bay: Results from the Environmental Monitoring and Assessment Program (EMAP)

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The EPA, with cooperation from NOAA and several other agencies, recently initiated a long-term trends monitoring program of Gulf Coast estuaries from northern Florida through Texas. The program, known as the Environmental Monitoring and Assessment Program: Louisiana Province Estuaries (EMAP-E), is designed to assess the overall (province wide) ambient conditions and trends of these coastal waters. The associated design can only provide rough estimates of any specific estuary. However, the results can be used to flag specific areas where further investigation may be warranted.

EMAP-E field crews visit probabilistically selected estuarine sites once each August or September (see Figure 1). The indicators EMAP-E focus on are fish and benthic community structure, contaminant levels in fish and bottom sediments, sediment toxicity (using *Ampelisca* and Mysids), and dissolved oxygen profiles.

Potential problems indicated from EMAP results of Galveston Bay sites include tributlytin concentrations in sediments throughout the Bay and pathologies in fish collected from the East Bay Bayou (Summers and Macauley, 1992).

Tributlytin in Sediments — Results from the 1991 EMAP-E study found tributlytin (TBT) concentrations of one or more ppb at 11 of 12 EMAP sediment samples collected from Galveston Bay and its associated tributaries and embayments. Five of the samples had concentrations higher than 5 ppb. By comparison, EMAP-E 1991 results estimate 9.6% of the Louisianian Province area (Gulf Coast from northern Florida through Texas) has sediment levels of TBT higher than 1 ppb.

Biological Impairment in East Bay Bayou of Galveston Bay: Fish Pathology and Sediment Toxicity — The highest pathology rates seen in the 1991 EMAP-E study occurred in East Bay Bayou (45% for Atlantic croaker and 65% for sand seatrout). The background rate for the Louisianian Province was < 1%. Significantly high mortality rates were also recorded from the sediment toxicity tests at the East Bay Bayou site. However, these results were based on only two samples each.

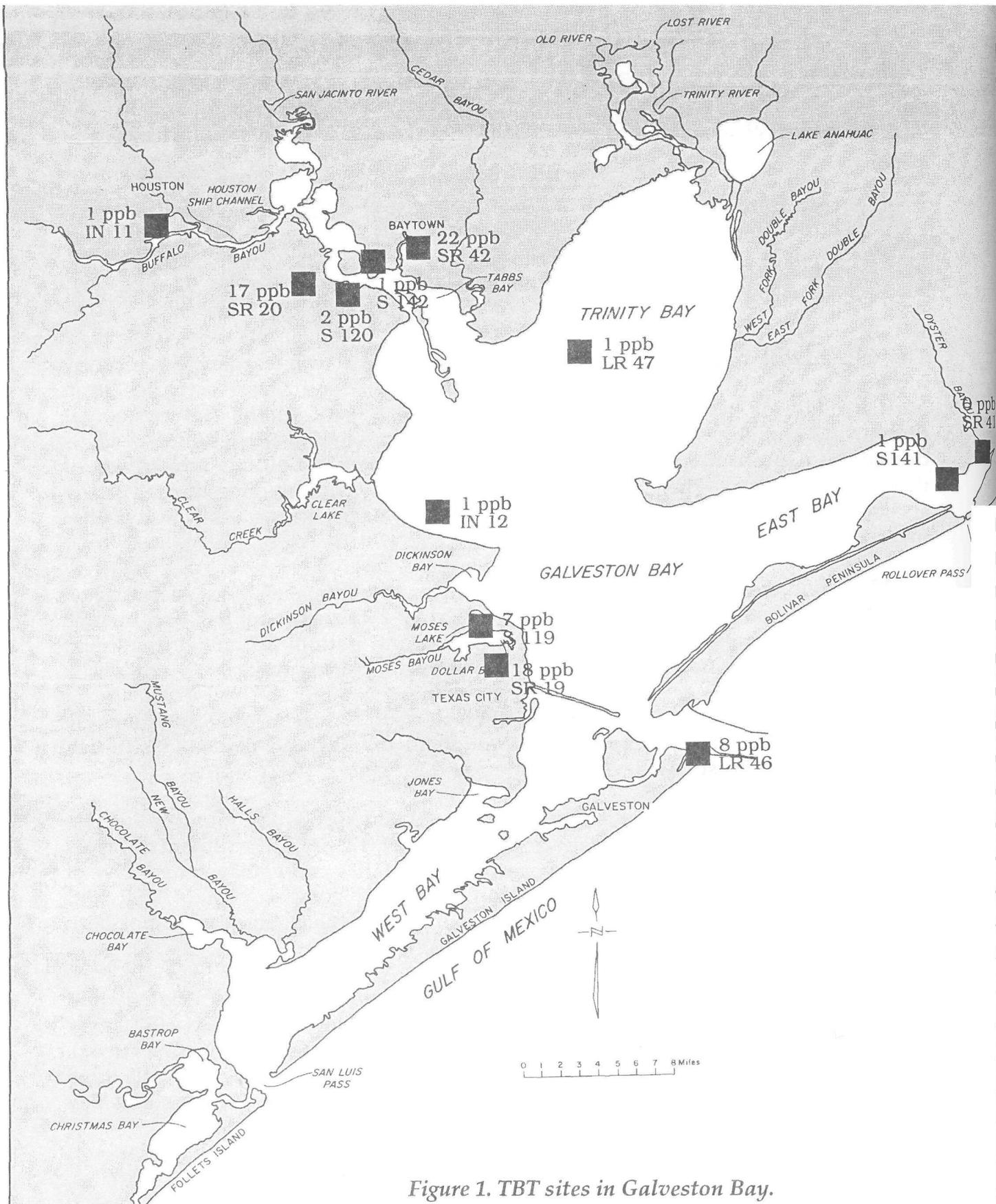


Figure 1. TBT sites in Galveston Bay.

Follow up investigations — EMAP is supporting a one time survey to further investigate these potential areas of concern in Galveston Bay. This survey will also be based on EMAP's probabilistically designed site selection, but with the spatial intensity of the sites increased (to yield 29 sites). The sites will be visited during September, 1993, and analyses will focus on TBT sediment levels in Galveston Bay and fish pathologies and sediment toxicity in East Bay Bayou (at six sites).

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Contaminant Assessment of the Upper Texas Coast

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Introduction

The Upper Texas Coast is defined in this report as the coastal bays, estuaries, and their tidally influenced tributaries from Freeport in Brazoria County northeastward to Port Arthur in Jefferson County. This section of the Texas coast has four major centers for petroleum and petrochemical manufacturing: Freeport, Texas City, Houston Ship Channel, and Port Arthur. Adjacent to these industrial areas are large municipal areas that house more than three million people. These urban areas contribute municipal waste (Gloyna and Molina, 1964), pesticides (Dick, 1982), and contaminated urban runoff (Newell et al., 1991) to the creeks, bayous, and rivers that drain into these coastal waters.

In 1964, Gloyna and Molina estimated there were 125 chemical plants in the Houston-Gulf Coast area and approximately 468 million gallons of domestic and industrial effluents per day were being discharged into the Galveston Bay system. Less than 20 years later, a report by Dames and Moore (1982) indicated that there were nearly 400 toxic and hazardous waste discharges and disposal sites located in the Houston-Baytown area. A recent report (Galveston Bay Foundation, 1992) reported that at least 70 toxic substances, which totaled 941,000 pounds, from only 31 industries were discharged in 1988 to the Houston Ship Channel. To date, there has been no assimilation of data for the Upper Texas Coast to even remotely estimate the number of discharges (municipal, industrial, or oil production), the tons of materials discharged, the chemical characteristics of the discharges, or the environmental fate of these chemicals. Gloyna and Molina (1964) recommended 28 years ago that, "Identification of such materials, estimates of persistence, and concentrations in aquatic forms should be made."

Environmental contaminants such as heavy metals, petroleum hydrocarbons, and hundreds of nonsoluble (i.e., hydrophobic) organic compounds are usually sorbed to sediment particles and carried into coastal bays and estuaries by rainfall runoff into the creeks, bayous, and rivers. Ekelund et. al. (1987) reported that suspended solids in water sorb the hydrophobic pollutants and increase the sediment contamination. Most of these contaminants are usually not bioavailable unless the sediments are disturbed and resuspended by currents, wave action, boat traffic, or dredging operations. Harrison (1967) discussed the environmental effects of dredging at the first world dredging conference. Ten years later, Morton (1977) stated that the possible remobilization of contaminants from dredged polluted sediments was a critical problem and the least understood. In 1973, a five-year program (i.e., the Dredged Material Research Program) was initiated and administered by the U.S.

Army Engineers Waterways Experiment Station in Vicksburg, Mississippi, to study the environmental effects of the Army Corps of Engineers dredging program.

Several studies concerning the effects of oilfield brine effluent (Armstrong et. al., 1979; Heffernan, 1972), industrial pollutants (King et. al, 1987), and heavy metals (Watling, 1982) on estuarine species suggest that there may be many contaminants in coastal estuaries. This study was designed to sample sediments and aquatic species from several locations on the Upper Texas Coast to document if highly contaminated areas are present, and if organisms are accumulating these contaminants. Previous assessments from Galveston Bay (Cain, 1989; King et al., 1986) suggested that contamination is present and could be responsible for adverse effects on aquatic species.

Methods

Sediment samples were collected from several bayous, creeks, bays, or ditches using a stainless steel petite ponar sampler. These 158 sediment samples were collected from 19 different locations. The sediment was removed from the ponar sampler with a stainless steel spoon and placed in a chemically cleaned jar, chilled, and transported to the laboratory. Some of the samples from the urban drains were lifted with a shovel and the inner portion removed with stainless spoon and placed in a jar. All jars were frozen at the laboratory and kept at -10°C until shipped frozen to the analytical laboratory.

Several species of animals were collected in 1988 from several places along the Upper Texas Coast. There were 206 samples that represented 19 species of aquatic invertebrates, fish, and birds. Locations used in the sampling were also used for the sediment samples collected in 1987. Oysters were collected from reefs or other structures in the water, pried open with a stainless steel knife, and the contents inside the shell was pored into a chemically cleaned jar. Each oyster sample was a composite of five oysters. Blue crabs were collected using standard commercial crab traps baited with mullet. Crabs were put in a plastic cooler with ice and transported to the laboratory. The chilled crabs were then pried open and the visceral and some gill tissue was put into a chemically cleaned jar. Each crab sample was a composite of five crabs. All fish were trapped in gill nets and removed from the net within eight hours of the net set. Only fish that smelled fresh were kept for tissue removal. Liver tissue was removed with a stainless steel pair of forceps and a scapel. Liver samples were a composite of three livers. Tissue samples from fish species were muscle tissue. Sea catfish that were small were composited three to a sample for whole body analysis. Bird species were only nestlings from the Houston Ship Channel disposal island. Each sample was a nestling that had the feet, bill, and wings removed. These nestlings were not feathered at the time of collection. All animal tissue samples were kept frozen and shipped to the analytical laboratory.

Analytes considered in this study consist of 21 heavy metals, 19 organophosphate pesticides, 15 organochlorine pesticides, 14 polycyclic aromatic hydrocarbons (PAH),

and 13 aliphatic hydrocarbons. Heavy metal residues are reported in parts per million (ppm) dry weight, and all other analytes are reported as ppm wet weight. In this study, one-half the detection limit for heavy metals in sediment samples was used.

Results

The mean residue concentrations for 19 heavy metals detected in the 146 sediment samples are presented in Table 1.

Table 1. General site description for each marina.

Heavy Metal	Mean	Range	Standard Deviation
†AL	17.9	38.8	7.3
AS	3.0	11.1	1.8
BO	5.4	98.0	10.7
BA	214.1	1481.9	173.8
BE	1.2	3.1	0.4
CD	0.5	18.9	1.7
CR	30.6	335.4	37.6
CU	19.9	241.7	23.2
†FE	16.7	34.4	5.6
HG	0.5	3.3	0.8
†MG	5.0	11.2	2.1
MN	320.7	2368.9	267.0
MO	1.3	8.3	0.9
NI	16.2	50.5	6.3
PB	43.8	888.0	96.2
SE	0.4	5.0	0.9
SR	136.8	2737.3	301.2
VA	16.6	34.4	6.2
ZN	149.5	7017.0	586.9

†Multiply values by 1000 for residue concentration.

The mean concentration of six of these metals (i.e., boron, cadmium, lead, selenium, strontium, and zinc) are exceeded by their respective standard deviation of greater than 100 percent. Contamination by that metal is either very high in one sample or in a certain location. These sediment samples were lumped into 18 distinct locations based upon a geographic feature (i.e., urban drainage or a certain embayment). The mean residue for each of the 19 metals by location are presented in Table 2. The mean value in bold type indicates a high level of contamination by that metal at that location. These results will be discussed in greater detail.

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Trace Organic Contamination in Galveston Bay Oysters: Results from the NOAA National Status and Trends Mussel Watch Program

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It is important to determine the current status of contaminant concentrations in order to assess the environmental response to management decisions that reduce or stop the input of selected contaminants. To fill this information gap with high quality data for U.S. coastal areas, the National Oceanic and Atmospheric Administration (NOAA) established the National Status and Trends (NS&T) Mussel Watch Program. As part of the NS&T Program, sediment and oyster samples have been collected and analyzed from over 70 estuarine sites in the Gulf of Mexico representing all major Gulf Coast estuaries. Sampling sites were located in areas not influenced by known point sources of contaminant inputs, including Galveston Bay. Oysters were employed as sentinel organisms because they are cosmopolitan, sedentary, bioaccumulate, able to provide an assessment of bioavailability, not readily capable of metabolizing contaminants, able to survive pollution loading, transplantable, and commercially valuable. Oysters are, therefore, excellent biomonitors for contamination in estuarine areas.

The Galveston Bay system is one of the largest and most economically important estuaries along the U.S. Gulf Coast. This area has been the recipient of various contaminant inputs because of an aggressively growing urban and industrial region. Houston, Deer Park, Baytown, Texas City and Galveston, surrounding Galveston Bay to the north and west, are some of the most heavily industrialized areas in Texas. Hundreds of industrial plants, including petrochemical complexes and refineries, bordering the Galveston Bay estuarine system, as well as runoff, are likely to introduce significant amounts of organic contaminants into the Bay. In general, ecological studies have suggested that the waters of Galveston Bay contained contaminants in sublethal amounts which caused stress to organisms resulting in significant changes in the estuarine community structure. Galveston Bay NOAA NS&T sampling sites (Figure 1) included the Ship Channel (GBSC), Yacht Club (GBYC), Todd's Dump (GBTD), Hanna Reef (GBHR), Offats Bayou (GBOB) and Confederate Reef (GBCR). Samples were collected in the winter starting in January of 1986 at four sites (GBYC, GBTD, GBHR, GBCR) and in December of 1987 (Year 3) at two additional sites (GBSC, GBOB). Samples were collected at some of these sites at other times to provide information on seasonal trends in contaminant concentrations. Sediments (top 1 cm) and oysters (20) were collected at three stations at each site and analyzed for polynuclear aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), chlorinated pesticides (e.g., DDT, chlordane), and

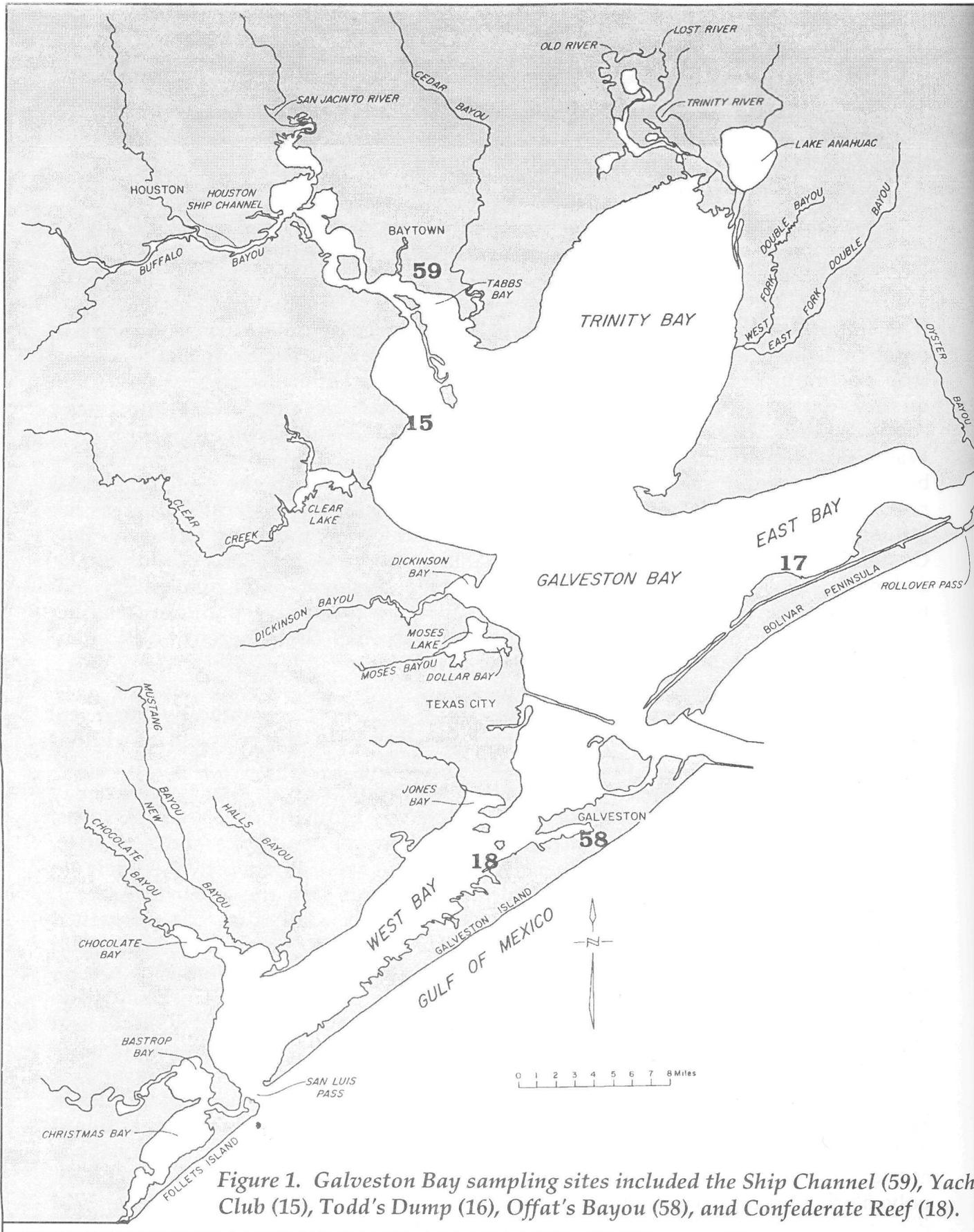


Figure 1. Galveston Bay sampling sites included the Ship Channel (59), Yach Club (15), Todd's Dump (16), Offat's Bayou (58), and Confederate Reef (18).

tributyltin. Sampling started in the winter of 1985/86 and is continuing with sampling each winter. Seven years of data are currently available and Year 8 sampling has just been completed. All sample analyses were performed using standard operating procedures (SOPs) to provide high quality, precise, accurate, and reproducible data. Data quality was further assured by yearly participation in NOAA/NIST intercalibration exercises. This allows for direct comparison of NS&T Gulf Coast data with NS&T data for the East and West coasts.

Contaminant concentration patterns were similar for most contaminants. The upper bay sites (GBSC, GBYC) had higher concentrations than the mid-bay sites (GBTD, GBHR) for PAH, DDT, PCB, and butyltins. Sites from the lower bay (GBOB, GBCR) had intermediate concentrations. This most likely results from proximity to large urban areas and runoff inputs. The lower contaminant loading in the mid-bay region probably results from dilution effects. For example, total PAH average concentrations ranged from 20 to 15,000 ng/g. The higher concentrations were measured in oysters from the upper portion of Galveston Bay (i.e., GBSC and GBYC) and near the city of Galveston (i.e., GBCR and GBOB). Oyster samples from areas farther away from urban centers (i.e., GBHR and GBTD) had average concentrations one to two orders of magnitude lower. In general, these concentrations are in good agreement with those previously encountered during temporal studies in Galveston Bay. Two PAHs, pyrene and fluoranthene, generally accounted for >25% of the total PAHs measured. The predominance of these compounds suggests that the major source of PAHs is from combustion products.

Average total PCB and DDT concentrations in Galveston Bay oysters were in the 48-1100 and 12-240 ng/g ranges, respectively. Most of the DDT residue is present as metabolites, DDE and DDD. In general, less than 10% of the total contaminant load in oysters is the parent compound, DDT. Samples from the GBYC and GBSC were the most contaminated while oysters from GBHR had the lowest residue concentrations. These concentrations agree with the ranges reported earlier for Galveston Bay bivalves. The median concentrations found in Galveston Bay for PAH, chlordane, dieldrin, PCB, and butyltins are higher than the median concentrations found throughout the Gulf of Mexico for the NS&T Program. The median DDT concentrations found in Galveston Bay are about the same as those found for the entire Gulf of Mexico. Therefore, compared to the rest of the Gulf of Mexico the median concentrations of most organic contaminants are generally higher in Galveston Bay. However, when Galveston Bay sites are compared to all U.S. NS&T sites none of the concentrations, with the exception of chlordanes at GBYC and GBSC, are ranked as high on a national scale.

Sample collections at other times of the year indicate some seasonal variability of contamination concentrations. This may result from the loss of a considerable amount of contaminants by oysters during spawning. Other studies of Galveston Bay oysters indicate that body burdens of contaminants can change due to accumulation and depuration. These preliminary studies indicate that more information regarding the use of oysters as bioindicators would provide for better interpretation of the data from the NS&T program.