CONTAMINANTS INVESTIGATION OF THE ARANSAS BAY COMPLEX, TEXAS, 1985-1986

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INTRODUCTION

Texas has approximately 1,419 miles of bay shoreline along which are located seven major bay systems: Sabine Lake, Galveston Bay, Matagorda Bay, San Antonio Bay, Copano-Aransas Bays, Corpus Christi Bay and the Laguna Madre. These bay and associated estuarine environments, with their total surface area of more than 1.3 million acres, are extremely productive, supporting multi-million dollar sports and commercial fisheries.

The productivity of these bay systems is threatened by many activities, including oil and gas production, surface mining, agricultural development, urbanization, and industrial expansion. In addition to the habitat loss associated with these activities, considerable quantities of environmental pollutants are discharged into coastal estuaries from point and non-point sources. Particular concern over such anthropogenic contaminants -prompted the Environmental Contaminants program of the Corpus Christi Ecological Services Field Office to initiate a comprehensive sampling plan to determine the magnitude and extent of this problem. The initial phase of the investigation concentrates on the bay complex that surrounds Aransas National Wildlife Refuge (San Antonio Bay and Aransas-Copano Bays) (Figure 1).

The Aransas National Wildlife Refuge, occupying more than 50,000 acres of Blackjack Peninsula on the Texas Gulf coast, consists of bays, tidal flats, marshes, and upland areas that support a broad assemblage of plants and animals. The refuge is bordered by San Antonio and Aransas bays. These areas are a major contributing factor to the Texas sport and commercial fishing industries by providing a nursery and feeding area for many species of f inf ish and shellfish. These areas also provide important nesting, feeding, and resting habitat for waterfowl and colonial-nesting waterbirds. Aransas National Wildlife Refuge is best known, however, as the historical wintering grounds of the endangered whooping crane (Grus americana). Maintenance of critical habitat at Aransas has contributed significantly to an increase in the population of this species from 15 birds in 1941, to approximately 80 birds in 1984, and to 138 birds in 1988 (Tom Stehn, personal communication). The whooping crane and many other species dependent upon the refuge and surrounding habitats may be seriously threatened, however, by chemical contaminants.

These bays and estuaries are virtually surrounded by agricultural, industrial, and petrochemical activities. Cotton and sorghum are the predominant crops grown in the area. Several organochlorine insecticides have been detected in bottom sediments of San Antonio Bay, including aldrin, DDD, DDE, DDT, dieldrin, endrin, heptachlor and heptachlor epoxide. These compounds have also been detected in fish from this area (Texas Department of Water Resources 1982a).

The Victoria Barge Canal, which traverses the northeastern boundary of San Antonio Bay east of the refuge, has several petrochemical plants situated along its course that discharge waste effluents into the canal. The Texas Department of Water Resources (1980a) found elevated levels of arsenic,

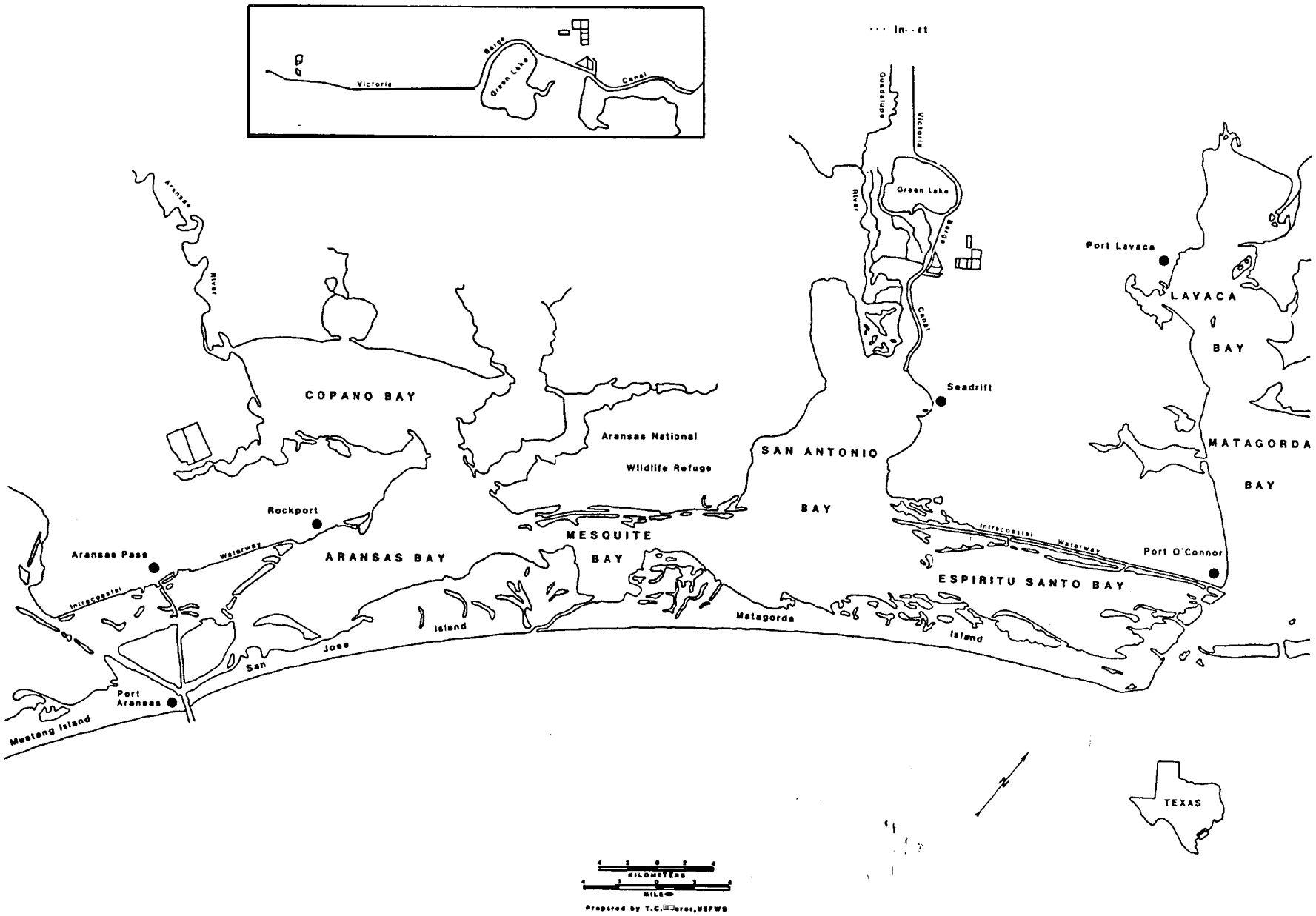

Figure 1. Location of the bay systems included in the Aransas Bay Complex study.

cadmium, chromium, mercury, and zinc in the bottom sediments of this bay. Transportation of chemicals to and from these industries and along the Gulf Intracoastal Waterway (GIWW) may also result in chemical contamination of estuarine resources as a result of accidental spills. For example, in 1983 a barge transporting acrylonitrile exploded and spilled its highly toxic contents into the barge canal.

Petrochemical and metal refining industries are abundant in the Lavaca Bay area north of San Antonio Bay. Contamination by arsenic, cadmium, mercury, and zinc have been documented in the past (Texas Department of Water Resources 1980b). High mercury levels have previously lead to the closure of shellfishing and finfishing in this area. Hydrological conditions may distribute these contaminants to other bay systems, including those in the immediate vicinity of the refuge.

This bay complex is richly endowed with oil and gas fields (Figure 2). As a result, oil and gas production operations are numerous, both onshore and in the bays. Both petroleum hydrocarbons and heavy metals may be released from these facilities or the pipelines transporting their products. Petroleum hydrocarbons, in particular, have a wide range of possible effects on marine organisms due to their complex chemical structure. Polycyclic aromatic hydrocarbons (PAHs), which are a constituent of petroleum hydrocarbons, are of major environmental concern due to the acute and chronic effects that have been associated with them (Eisler 1987a). The cumulative effects of these discharges could be extremely damaging to the ecosystem.

This report presents the levels of organochlorines, PCBs, trace elements, and petroleum hydrocarbons in sea catfish (Arius felis), blue crabs (Callinectes sapidus), and eastern oyster (Crossostrea virginica). Concentrations of trace elements and oil and grease in sediments are also presented. The contaminant levels in biota and sediment are examined in order to assess the potential effects various contaminants may have on the fish and wildlife resources of this bay complex.

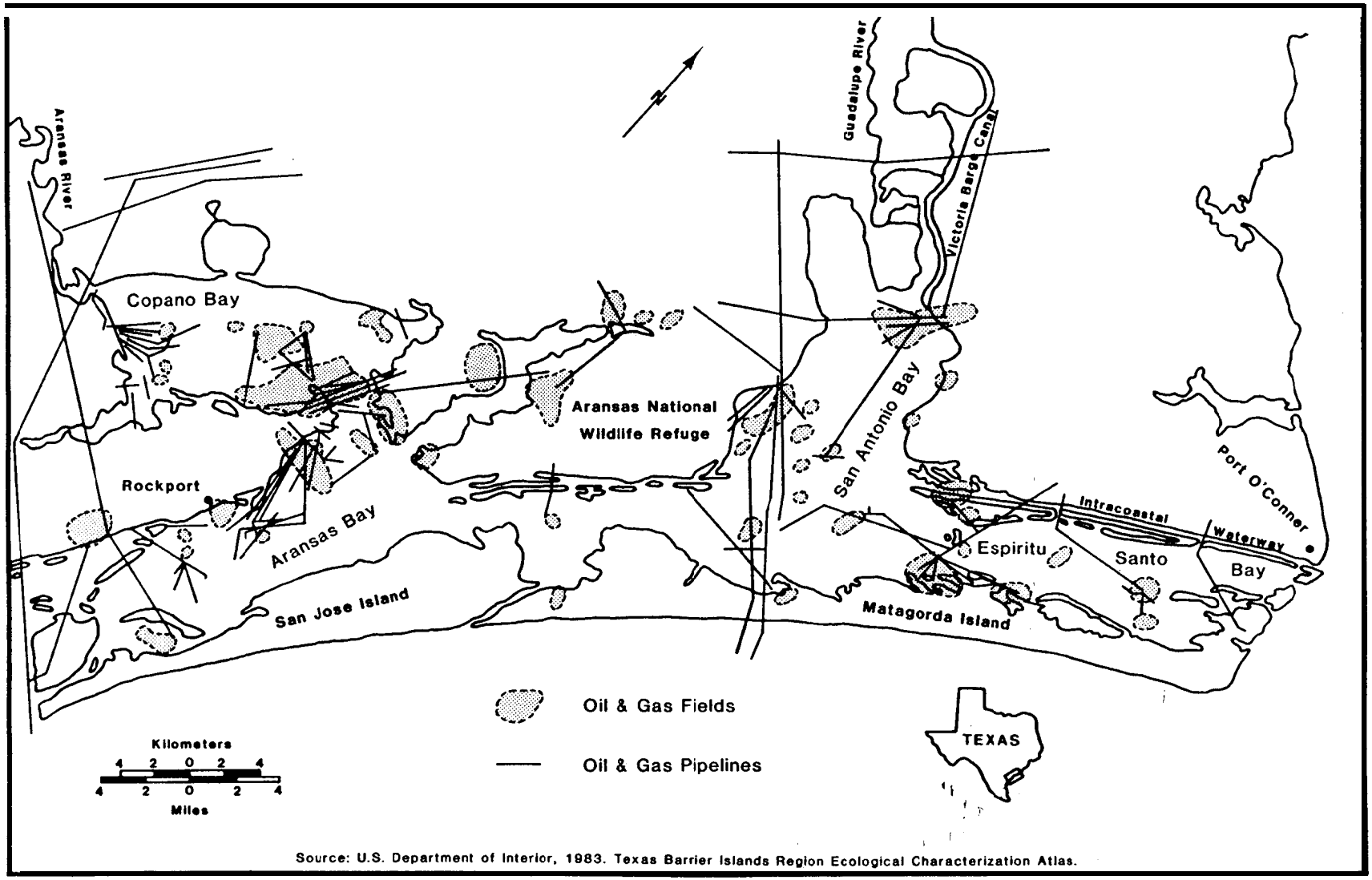

Figure 2. Location of oil and gas fields and pipelines in the Aransas Bay Complex.

METHODS AND MATERIALS

Sediment

Sediment was collected at 378 sites in the Aransas Bay Complex from Port O'Connor to Port Aransas in July, August, and September 1.985. Site locations were established using a one-mile grid system aligned to magnetic north. Additional sites along the Gulf Intracoastal Waterway, the Victoria Barge Canal, and whooping crane feeding areas were selected. Figure 3 shows the locations of sediment sample sites.

Locations were determined in the field by traveling at a known speed along a compass reading for the amount of time to travel one mile. Triangulation using channel markers, islands, oyster reefs, drilling platforms-and other fixed objects aided in locating sites. Where grid sites occurred on oyster reefs, islands, or shorelines, their location were moved to the nearest areas where sediments were found.

Samples were collected with a stainless steel Ekman dredge or a stainless steel Ponar dredge. A dredge sample from each site was placed in a deep stainless steel pan and the top 15 cm of sediment were removed. Samples were placed in two separate quart glass jars with teflon lid liners. Jars and lid liners were chemically cleaned with acid and organic solvents according to Environmental Protection Agency (EPA) procedures (EPA 1982a).

Oil and grease concentrations were determined for all 378 samples and trace elements were determined for 201 of the samples. The 201 sediment samples were analyzed for 23 trace elements (Table 1) at the Environmental Trace Substance Research Center in Columbia, Missouri. Inductively coupled plasma emission spectroscopy was used to determine all of the elements except arsenic, selenium, and mercury. Arsenic and selenium were determined by hydride generation with atomic absorption. Cold vapor reduction was used for the mercury analysis. Blanks, duplicates, spiked samples, and standards were used for quality control and quality assurance and were monitored by the Service's Patuxent Analytical Control Facility (Patuxent). Oil and grease analysis was performed at the Anacon Analytical and Consulting Laboratories in Pasadena, Texas. Quality control was performed according to EPA standards. Nominal detection limits for chemicals and elements analyzed in sediment for this study are given in Table 2.

Biota

Sea catfish, blue crab, and eastern oysters were collected at 65 sites throughout the Aransas Bay Complex, Lavaca and Matagorda bays in September and October of 1986 (Figure 4 and 5). Biota samples from Lavaca and Matagorda bays were included because of the adjacency of these bays to the Aransas Bay Complex and the history of mercury contamination in Lavaca Bay. Blue crab were collected at all 65 sites, sea catfish at 11 sites, and eastern oysters at 9 sites.

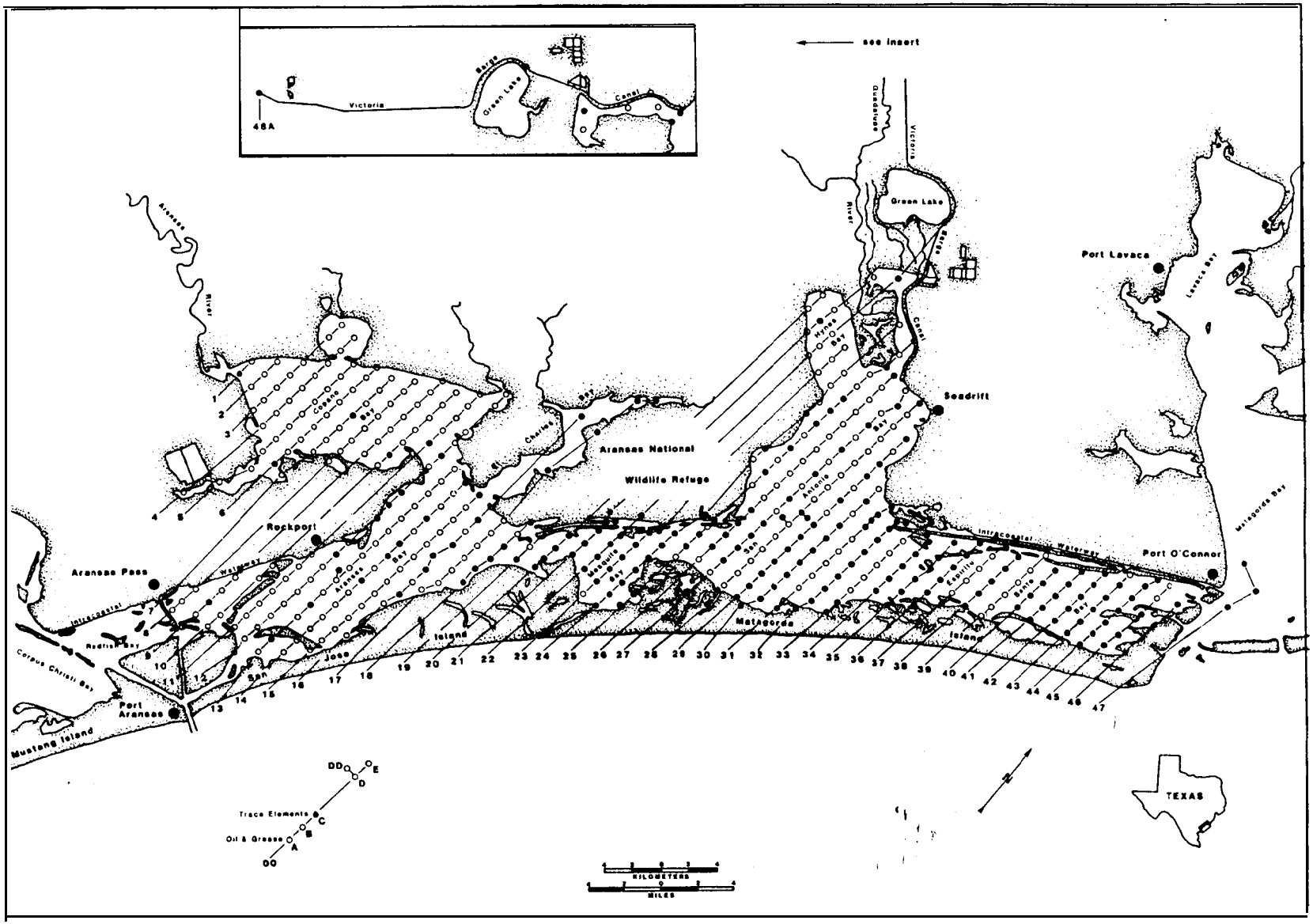

Figure 3. Location of sediment sample sites in the Aransas Bay Complex.

Table 1. Compounds and elements analyzed in sediment and biota from the Aransas Bay Complex, Texas,-1985-86.

ALKANES[1]	ORGANOCHLORINES[1]	ELEMENTS[2]
n-DODECANE (n-C12)[3]	OXYCHLORDANE	ALUMINUM (AL)
n-TRIDECANE (n-C13)	c-CHLORDANE	ANTIMONY (SB)[4]
n-TETRADECANE (n-C14)	t-CHLORDANE	ARSENIC (AS)
OCTYLCYCLOHEXANE (n-C14)	c-NONACHLOR	BARIUM (BA)
n-PENTADECANE (n-C15)	t-NONACHLOR	BERYLLIUM (BE)
NONYLCYCLOHEXANE	HEPTACHLOR	BORON (B)
n-HEXADECANE (n-C16)	HEPTACHLOR EPOXIDE	CADMIUM (CD)
n-HEPTADECANE (n-C17)	METHOXYCHLOR	CHROMIUM (CR)
PRISTANE	o,p'-DDE	COPPER (CU)
n-OCTADECANE (n-C18)	o,p'-DDD	IRON (FE)
PHYTANE	o,p'-DDT	LEAD (PB)
n-NONADECANE (n-C19)	PIP'-DDE	MAGNESIUM (MG)
n-EICOSANE (n-C20)	PIP'-DDD	MANGANESE (MN)
n-HENEICOSANE (n-C21)	p,p'-DDT	MERCURY (HG)
	ENDRIN	MOLYBDENUM (MO)
	DIELDRIN	NICKEL (NI)
	ALDRIN	SELENIUM (SE)
	alpha-BHC	SILVER (AG)
	beta-BHC	STRONTIUM (SR)
	gamma-BHC	THALLIUM (TL)
	delta-BHC	TIN (SN)[4]
AROMATIC HYDROCARBONS[1]	HEXACHLOROBENZENE	VANADIUM (V)
	ENDOSULFAN I	ZINC (ZN)
NAPHTHALENE	ENDOSULFAN II	
FLUORENE	ENDOSULFAN SULFATE	
PHENANTHRENE	MIREX	
ANTHRACENE	DCPA	
FLUORANTHRENE	DICOFOL	
PYRENE	TETRADIFON	
1,2-BENZANTHRACENE	AROCHLOR 1221	
CHRYSENE	AROCHLOR 1016	
BENZO (b) FLUORANTHRENE	AROCHLOR 1232	
BENZO (k) FLUORANTHRENE	AROCHLOR 1242	
BENZO (e) PYRENE	AROCHLOR 1248	
BENZO (a) PYRENE	AROCHLOR 1254	
1,2,5,6-DIBENZANTHRAC	AROCHLOR 1260	
	AROCHLOR 1262	
	TOTAL PCB'S	
BENZO (g,h,i) PERYLENE	TOXAPHENE	

[1] BIOTA ONLY
[2] BIOTA AND SEDIMENT
[3] CARBON NUMBER IN THE COMPOUND
[4] SEDIMENT ONLY

Table 2. Nominal detection limits of analytical methods used in the analysis of sediment and biota samples collected from the Aransas Bay Complex, Texas, 1985-86.

CHEMICAL	BIOTA UG/G (WET WT)	SEDIMENT UG/G (DRY WT)
SE	0.5	0.2
HG	0.5	0.05
AS	0.5	0.2
AG	0.2	0.3
AL	1.0	10.0
B	5.0	1.0
BA	0.1	0.1
BE	0.1	0.1
CD	0.1	0.2
CR	0.1	1.0
cu	0.1	1.0
FE	1.0	3.0
MG	1.0	0.2
MN	1.0	0.1
MO	0.1	2.0
NI	0.1	2.0
PB	0.2	3.0
SB	---[1]	3.0
SN	1.0	2.0
SR	0.1	0.1
TL	0.3	7.0
V	0.1	1.0
ZN	1.0	1.0
ALKANES	0.03	----
ORGANOCHLORINES	0.01	0.01
TOXAPHENE	0.25	0.05
PCB's	0.25	0.05
PETROLEUM AROMATIC HYDROCARBONS	0.03	0.01

[1] ---- NOT ANALIZED

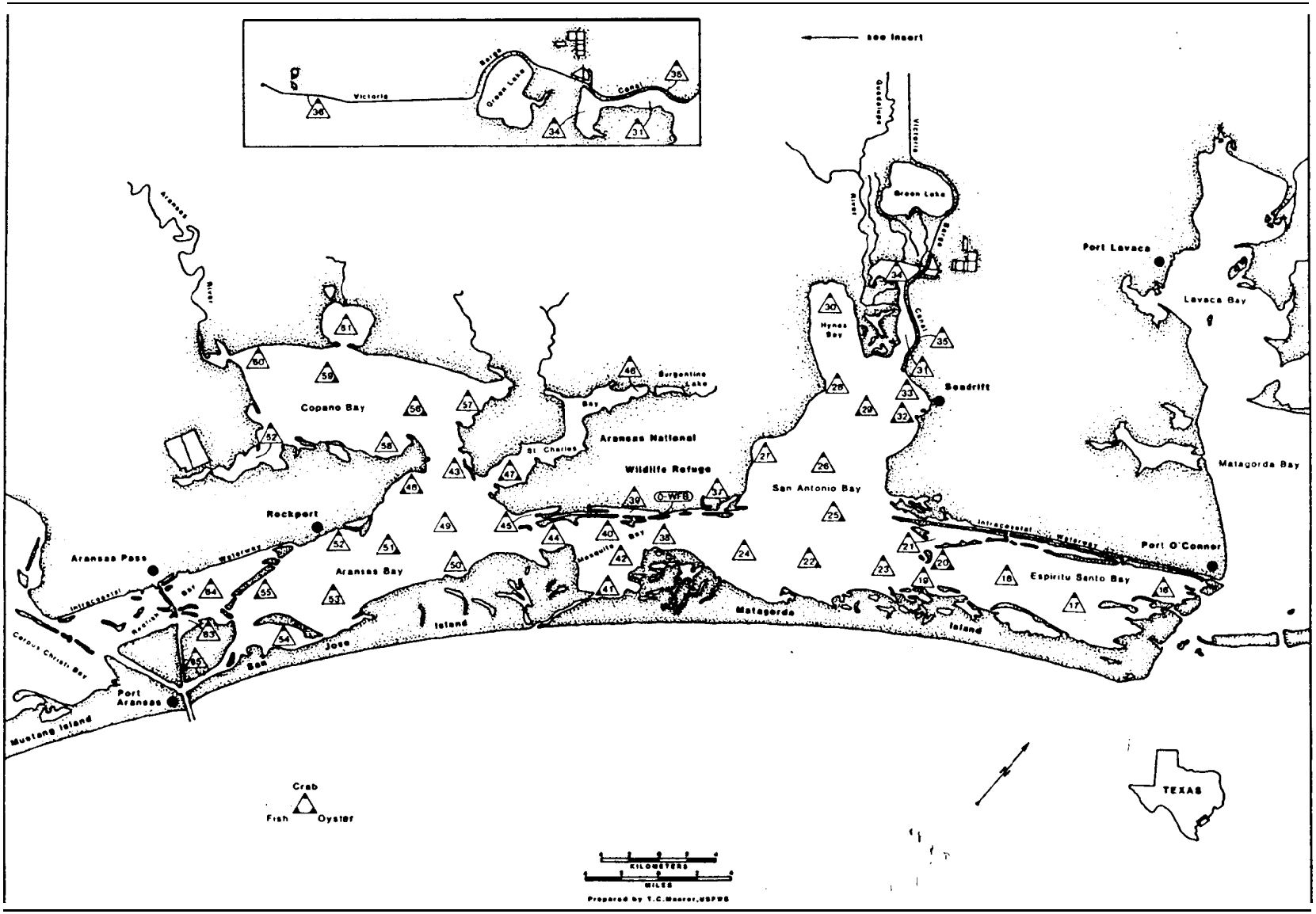

Figure 4. Location of biota collection sites in the Aransas Bay Complex.

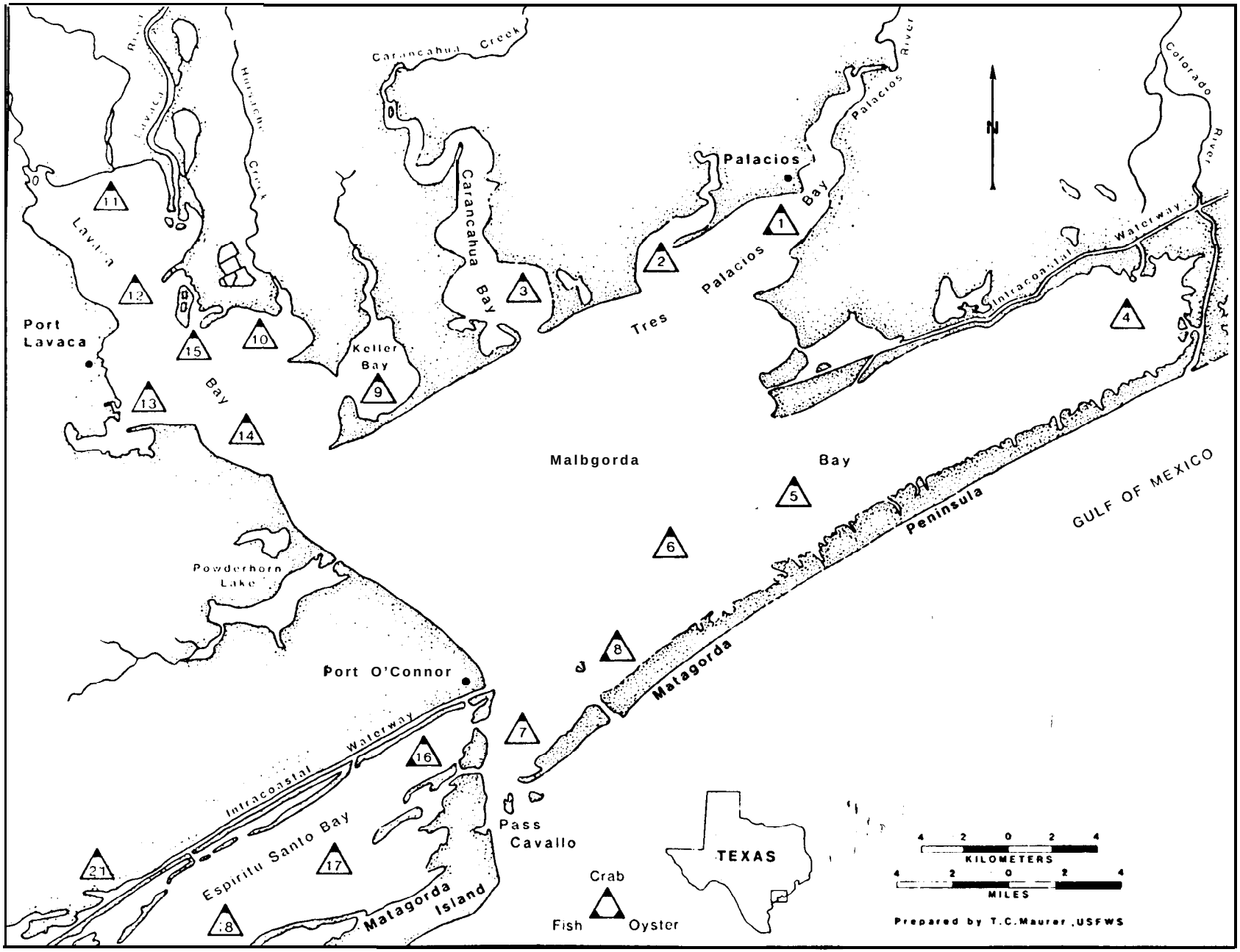

Figure 5. Location of blue crab sample site location in Lavaca Bay and Matagorda Bay.

Site locations for biota were selected to cover all types of estuarine habitats (open bay, marsh, grass beds, oyster reefs, river deltas). Specific areas of known or suspected contamination were of primary importance, as were whooping crane feeding areas,

Blue crabs were collected using gill nets and crab traps. A composite of five individuals (including exoskeletons) made up a sample. Sea catfish were collected using three inch mesh monofilament gill nets, set lines, and by angling. A sample consisted of a composite of five fish (whole body). Tongs on twelve-foot-long poles were used to collect eastern oysters. Oysters were shucked in the field and the soft parts placed in jars. The jars were cleaned in the same manner as the sediment jars, Approximately one pint of oyster tissue was collected from each site. Upon collection, all samples were kept on ice until they could be frozen.

Analyses of 21 trace elements were performed at the Trace Substance Research Center in Columbia, Missouri. Trace elements were determined using inductively coupled plasma emission spectroscopy. Hydride generation with atomic absorption was used for arsenic and selenium determination and cold vapor reduction was used for mercury. Preconcentration methods were used to enhance detection limits for cadmium, copper, molybdenum, nickel, lead, thallium, vanadium, and zinc.

Organic analyses were performed at Weyerhaeuser Analytical and Testing Services in Tacoma, Washington. Aromatic hydrocarbons, alkanes, and organochlorines were determined using gas chromatography with mass spectrophotometry for confirmation. The Patuxent Analytical Control Facility monitored quality control at these laboratories. Nominal detection limits for the chemicals and elements that were analyzed in biota for this study are given in Table 2.

Data Analysis

Minimum and maximum values were determined for all organochlorine, trace element, and petroleum hydrocarbon concentrations found above detection limits. Geometric means were determined in those instances where more than 50 percent of the samples were above detection limits. In those cases where geometric means were calculated, one-half the detection limit was used for those samples below detection limit. The numerical log of each value was taken and then the mean of the logs was calculated. The antilog of the mean was then taken to convert the value back to the arithmetic scale.

The results for organochlorine contaminants are reported in parts per billion (ppb) in tables and text because of the consistently low level of detection. All trace elements and petroleum hydrocarbons are presented in parts per million (ppm).

RESULTS AND DISCUSSION

Orqanochlorines

Fourteen organochlorines were found above the detection limits in biota samples. Chlordane isomers (oxychlordane, cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor) and DDT metabolites were-the compounds most frequently detected. Despite the high frequency of detection, most organochlorines were detected at very low concentrations. Neither toxaphene nor any PCB compounds were found above detection limits. Table 3 presents the ranges and geometric means of the organochlorines most frequently detected in biota samples.

DDT and Metabolites

The most persistent DDT metabolite, DDE, was detected in all biota samples. The concentrations of DDE were higher than any of the other organochlorines, with the highest concentrations occurring in sea catfish (geometric mean was 95 ppb wet weight). The concentrations of DDE in blue crab and oyster samples (geometric means of 11 ppb and 10 ppb, wet weight) was much lower than that in sea catfish. DDD and DDT were found above the detection limit in fewer biota samples and at much lower concentrations than DDE.

These residues are lower than those detected in past studies. Childress (1970, as cited in Dick 1982) analyzed striped mullet (whole body) from San Antonio Bay and detected DDT, DDD, and DDE at 1500 ppb, 900 ppb, and 820 ppb, respectively. Sea catfish from this study had maximum concentrations of DDT, DDD, and DDE of 6 ppb, 22 ppb, and 340 ppb, respectively. Eastern oysters collected between 1965 to 1972 from San Antonio Bay, had maximum concentrations of total DDT (the sum of DDT, DDD, and DDE concentrations) of 488 ppb and oysters from Aransas Bay had maximum concentrations of 83 ppb (Butler 1973). The maximum level of total DDT in oysters for this study was 33 ppb, for a sample from San Antonio Bay.

The National Academy of Sciences and National Academy of Engineers (1972) established a level of 1000 ppb of total DDT as the recommended level for protection of aquatic life. All samples in this study were below this level. The geometric means for sea catfish, blue crabs, and oysters (whole body, wet weight) were 107 ppb, 17 ppb, and 17 ppb, respectively. Even the maximum concentration for total DDT (365 ppb in a sea catfish sample) was well below the 1000 ppb level.

When the potential of biomagnification is considered, the levels of DDT and its metabolites are still relatively low. DDE concentrations of 3000 ppb in the diet of some birds may result in eggs with shells that are 12 to 14 percent thinner than normal (Mc Lane and Hall 1972, Lincer 1975). Lincer (1975) determined that a diet containing 1000 ppb DDE for two to three months prior to nesting would result in eggshells that are seven percent thinner. Some egg loss becomes evident with eggshell thinning of 10 to 15 percent, and

Table 3. Geometric means and ranges (ppb wet weight) of organochlorines in biota from the Aransas Bay Complex, Texas, 1985-1986.

Organochlorine	Sea Catfish n=11	Blue Crab n=65	Oyster n=9
p,p' DDE	95 (28-34) 11	11 (4-40) 65	10 (5-14) 9
p,p' DDD	10 (4-22) 11	6 (3-55) 63	5 (7-20) 6
p,p' DDT	--- (5-6) 3	--- (6-8) 2	BDL
Oxychlordane	2[1] (1-8)[2] 11[3]	2 (1-6) 65	2 (1-13) 11
c - Chlordane	2 (1-3) 11	1 (1-3) 61	--- (3-4) 3
t - Chlordane	2 (1-3) 11	1 (1-3) 41	4 (1-6) 9
c - Nonachlor	2 (1-4) 11	1 (1-4) 65	2 (1-4) 9
t - Nonachlor	6 (3-10) 11	2 (1-7) 65	3 (1-5) 9
HE[4]	2 (1-3) 11	1 (1-4) 43	2 (1-8) 6
Methoxychlor	3 (1-12) 9	--- (1-14) 29	BDL[4]
Endrin	3 (2-6) 10	1 (1-8) 45	--- (4) 1
Dieldrin	3 (2-6) 10	2 (1-6) 62	6 (1-15) 9
HCB[4]	1 (1-3) 11	1 (1-4) 64	4 (1-34) 9
ES[4]	--- (4) 1	--- (1-4) 13	--- (2) 1

[1] Geometric mean (Geometric mean calculated only for those with > 50% detection).
[2] Range in parenthesis
[3] Number of samples above detection
[4] BDL = Below detection limit, HE = Heptachlor epoxide, HCB = Hexachlorobenzene, ES = Endosulfan sulfate

thinning that exceeds 15 percent is generally considered serious and may be associated with population decline (Hickey and Anderson 1968, Risebrough et al. 1970, Anderson and Hickey 1970). Therefore, the data from this study indicates that the DDE levels in fish, crabs, and oysters have likely caused only a slight degree of eggshell thinning, and that the degree of thinning is not expected to be at levels associated with egg loss. The data indicates that wintering whooping cranes, which feed heavily on blue crabs and clams, would be exposed to very low levels of DDT family compounds. These levels are not likely to have affected their reproductive success. Fish-eating birds in the study area, such as the brown pelican (Pelecanus occidentalis), have been exposed to slightly higher levels of these compounds. The levels detected are likely to have caused a slight degree of eggshell thinning, but not enough to result in egg loss.

Chlordane Isomers

The chlordane isomers were detected in most of the biota samples. Cis-chlordane was detected in only three of nine oyster samples and trans-chlordane was detected in 41 of 65 blue crab samples. Trans-chlordane is relatively unstable compared to other chlordane isomers (Kawano et al. 1988). Despite the high frequency of detection, the concentrations of chlordane isomers were quite low. The highest concentration for a chlordane isomer was 13 ppb oxychlordane in an oyster sample. The geometric means of chlordane isomers in biota samples ranged from 1 ppb to 6 ppb.

Chlordane has received attention in recent years due to the presence of elevated levels in the environment in certain regions of the United States (Arruda et al. 1987, Kansas Department of Health and Environment 1987, Arruda et al. 1988). These elevated levels of chlordane isomers have usually been associated with rivers downstream of major urban areas (Kansas Department of Health and Environment 1987). This situation has been attributed to the use of chlordane for subterranean termite control in urban areas.

The National Academy of Sciences and National Academy of Engineers (1972) established a level of 100 ppb for a single chlordane isomer or total chlordane (the sum of oxychlordane, cis-chlordane, trans-chlordane, cis-nonachlor, and trans-nonachlor) as a recommended level for protection of aquatic life. This level was not exceeded by any of the biota samples from this study. The geometric means for total chlordane for sea catfish, blue crab, and oysters were 14 ppb, 7 ppb, and 12 ppb, respectively, and the maximum concentration of total chlordane was 31 ppb in an oyster sample. The low levels of the chlordane isomers and the lack of any major urban area located on these bays or nearby in the watersheds indicates that most of the chlordane detected was likely due to agricultural use prior to the 1980 ban of chlordane for such uses.

The remaining organochlorine compounds that were detected (heptachlor epoxide, methoxychlor, endrin, dieldrin, hexachlorobenzene, endosulfan sulfate) were

found at levels only slightly above detection and were below levels considered to be biologically significant.

Trace Elements

Twenty-one of 23 trace elements were found above the detection limit in sediment. Molybdenum and tin were the only elements not found above detection in sediment samples. In biota, 19 of 21 trace elements were found above the detection limits. Silver and thallium were below detection in all biota samples. In sea catfish, two additional elements, chromium and molybdenum, were below detection. The geometric means and ranges of selected trace elements in sediment, sea catfish, blue crab and oysters are presented in Table 4. Table 5 presents the geometric means of selected trace-elements in blue crabs from individual bays.

Arsenic

Arsenic was detected in all sediment samples. The geometric mean was 1.8 ppm (dry weight), with a minimum of 0.5 ppm and maximum of 5.0 ppm. All biota samples contained detectable levels of arsenic. The highest average concentrations were detected in sea catfish with a geometric mean of 2.1 ppm (wet weight). The geometric mean of arsenic in blue crabs and oysters was 1.4 ppm and 0.8 ppm respectively. The highest concentration detected in a biota sample was 7.0 ppm in a sea catfish composite.

Arsenic is a trace element that often receives special interest because of its ability, at elevated levels, to produce mutagenic, teratogenic, and carcinogenic effects in mammals (Nagymajtenyi et al. 1985). Concentrations in most organisms are less than 1 ppm; however, marine organisms are an exception (Eisler 1988a). Marine biota have the ability to accumulate arsenic from seawater and food and typically have higher concentrations than freshwater organisms (Maher 1985). These higher concentrations are generally not considered harmful either to the organism or to human consumers. This is because the major form of arsenic in marine organisms (arsenobetaine) is considered relatively harmless (Kaise et al. 1985).

Marine finfish tissues usually contain 2 to 5 ppm; however, higher concentrations are not unusual (Eisler 1988a). The sea catfish samples from the Aransas Bay Complex are generally within this range. The one sample containing the maximum concentration (7.0 ppm), although slightly elevated above other samples, is not at a level of concern. The levels in sea catfish from this study were slightly higher than those in sea catfish from the Lower Laguna Madre and South Bay, Texas, where arsenic concentrations ranged from 0.3 to 4.7 ppm (geometric mean = 1.5 ppm) (Gamble et al. 1988). The concentrations in blue crabs and oysters were at levels considered to be within normal ranges and below levels of concern (Hall et al. 1978, NOAA 1987).

Table 4. Geometric means and ranges (ppm) of selected trace elements in sediment (dry weight) and biota (wet weight) from the Aransas Bay Complex, Texas, 1985-86.

Trace Element	Sediment n=201	Sea Catfish n=11	Blue Crab n=65	Oyster n=9
As	1.8[1] (0.5-5.0)[2] 201[3]	2.1 (0.4-7.0) 11	1.4 (0.2-5.7) 65	0.8 (0.5-1.2) 9
Cd	--- (0.3-0.5) 6	0.04 (0.02-0.05) 11	0.18 (0.01-0.88) 65	0.70 (0.48-1.21) 9
Cr	5.9 (2.0-20.0) 179	BDL[4]	0.11 (0.04-0.27) 38	0.10 (0.07-0.16) 9
Cu	3.2 (0.4-22.0) 197	0.06 (0.4-1.6) 11	11.8 (4.4-22.2) 65	21.1 (9.9-37.7) 9
Pb	5.1 (4.0-19.0) 133	0.19 (0.11-0.39) 11	0.10 (0.01-2.18) 62	0.07 (0.04-0.13) 9
Hg	--- (0.05-0.09) 8	0.173 (0.071-0.315) 11	0.038 (0.017-0.591) 65	0.008 (0.004-0.012) 9
Ni	4.8 (1.0-15.0) 187	0.05 (0.03-0.11) 11	0.10 (0.03-0.39) 65	0.27 (0.23-0.31) 9
Se	--- (0.20-5.10) 51	0.78 (0.61-0.92) 11	0.62 (0.29-1.02) 65	0.38 (0.33-0.46) 9
Zn	16.7 (0.2-79.2) 200	146.9 (79.0-229.1) 11	22.1 (11.8-52.5) 65	125.6 (68.9-221.5) 9

[1] Geometric mean (Geometric mean calculated only for those with › 50% detection).
[2] Range in parenthesis
[3] Number of samples above detection
[4] BDL = Below detection limit

Table 5. Geometric means of elements in blue crab (ppm wet weight) from individual bays of the Aransas Bay Complex, Texas, 1985-86.

	Aransas n=15	Copano n=7	Mesquite n=7	San Antonio n=15	Espiritu Santo n=4	Lavaca n=7	Matagorda n=8	Total n=65
AS	2.16	1.6	1.3	0.6	2.2	1.9	2.4	1.4
CD	0.23	0.32	0.2	0.15	0.17	0.16	0.18	0.18
CR	0.11	0.13	0.11	0.08	0.15	0.13	0.13	0.11
CU	11.3	13.7	11.6	11.2	13.2	11.1	13.3	11.8
PB	0.08	0.06	0.11	0.08	0.23	0.12	0.11	0.10
HG	0.033	0.036	0.028	0.027	0.032	0.113	0.047	0.038
NI	0.06	0.09	0.11	0.13	0.13	0.09	0.12	0.10
SE	0.61	0.79	0.72	0.57	0.62	0.61	0.58	0.62
ZN	18.6	24	23.3	21.8	22.1	22.4	24.7	22.1

Cadmium

Cadmium was found above detection limits in only six of 201 sediment samples. All biota samples contained detectable levels of cadmium. The highest mean levels in biota samples were detected in oyster samples, with a geometric mean of 0.70 ppm (wet weight). The geometric means of cadmium in blue crabs and sea catfish were 0.18 ppm and 0.04 ppm, respectively. The highest concentration detected in a biota sample was 1.21 ppm in an oyster sample from Copano Bay. When the levels of cadmium in blue crabs from individual bays are examined (Table 5), the concentrations are relatively uniform; however, the concentration in blue crabs from Copano Bay is slightly higher than other bays.

Cadmium is generally considered a nonessential trace element (Eisler 1985a). It is potentially toxic to most fish and wildlife at sufficient concentrations: freshwater organisms are especially sensitive. Marine biota typically contain much higher concentrations than freshwater organisms. This has been attributed to the higher levels of cadmium in seawater (Eisler 1985a).

Eisler (1971) determined in a laboratory study with the mummichog (Fundulus heteroclitus), an estuarine fish, that whole body fresh weight (fresh weight is synonymous with wet weight) concentrations exceeding 5.0 ppm were potentially lethal. And in general, concentrations exceeding 2.0 ppm whole body, fresh weight, in vertebrate animals is considered evidence of probable cadmium contamination (Eisler 1985a). The concentration of cadmium in all sea catfish samples from this study (maximum = 0.05 ppm whole body wet weight) were well below these levels.

Eisler (1985a) noted that cadmium tends to biomagnify in the lower trophic levels. The data from this study agrees with this determination. The concentrations in blue crabs were slightly higher than those in sea catfish and the concentrations in oysters were higher still. Determinations of threshold levels of concern have not been made for blue crabs or oysters.

Of 145 sample sites along the United States coast examined for the 1986 National Status and Trends Program (NOAA 1987), Copano Bay had the highest levels of cadmium (13 ppm dry weight) in oysters. The two oyster samples from this investigation with the highest concentrations of cadmium were collected from Copano Bay. One sample contained 17.1 ppm cadmium (dry weight) and the other 12.2 ppm. The cadmium concentrations in the seven other samples from other bays were approximately half these concentrations. Although the levels in Copano Bay are elevated, they are probably of greatest concern to human consumers. Eisler (1985a) determined that wildlife dietary intake exceeding 0.10 ppm cadmium (fresh weight) on a sustained basis should be viewed with caution, and extended this to humans. Phillips and Russo (1978) warned that oysters are capable of accumulating extremely high levels of cadmium in edible portions and thus represent a potential hazard to human consumers. The

elevated levels of cadmium could have implications for whooping cranes, which at times feed heavily on a variety of clams. The elevated levels in oysters may indicate that other bivalves have elevated levels. Currently the whooping cranes seldom feed in Copano Bay: however, as the population expands this bay may become an important feeding area.

The source of cadmium has not been determined. Anthropogenic sources of cadmium include fertilizers, municipal wastewater, smelter dust and the products of cadmium-bearing materials in fossil fuels. Cadmium was seldom detected above quantification in sediment in any of the bays, perhaps because the lowest detection limit for sediment samples was 0.3 ppm. A lower detection limit might have revealed some difference between Copano Bay and other bays. There are no major industries or municipalities along Copano Bay, or in the watershed. However, there are significant oil and gas fields in Copano Bay (Brown et al. 1976, McGowen et al. 1976, Texas Department of Water Resources 1982b). The production of oil and gas from these fields is one of the main industrial activities in the bay and may be a contributor of cadmium. Other possible sources include the few small municipal discharges and adjacent agricultural applications of fertilizers. Further investigation will be necessary to determine the importance of cadmium in oysters in Copano Bay and its source(s).

Chromium

Chromium was detected in 179 sediment samples from 2.0 to 20.0 ppm. Chromium was found above detection in 38 blue crab samples and all oyster samples. It was below detection limits in all sea catfish samples. The concentrations of chromium were low in biota samples, with a geometric mean of 0.11 ppm in blue crabs and 0.10 ppm in oysters. There was very little variation in chromium levels in blue crab samples between bays.

Chromium is known to have both lethal and sublethal effects on fish and wildlife. However, the significance of tissue residues is imperfectly understood. Current evidence suggests that tissue levels of fish and wildlife in excess of 4.0 ppm dry weight are indicative of chromium contamination (Eisler 1986). When dry weight conversions were made for our data, all concentrations were well below the 4.0 ppm dry weight level. The highest dry weight concentration was 2.3 ppm in an oyster sample.

Copper

Copper was detected above quantification limits in 197 sediment samples and all biota samples. The highest geometric mean concentrations were detected in oysters at 21.1 ppm (wet weight). The geometric mean of copper in blue crabs was approximately half that found in oyster samples (11.8 ppm). Copper levels were lowest in sea catfish with a geometric mean of 0.06 ppm. Comparison of copper levels in blue crabs from individual bays revealed there was little variation between the bays.

Copper is an essential element for both plants and animals. At sufficient concentrations copper may also be toxic to a variety of fish and wildlife (EPA 1980). Breteler (1984) identified copper as one of the major threats to ecosystem health relative to other heavy metals.

The concentrations of copper in sea catfish were generally-low (geometric mean = 0.06 ppm wet weight). Sea catfish collected in the Lower Laguna Madre and South Bay, Texas (Gamble et al. 1988), contained geometric mean levels of 0.36 ppm (wet weight). Custer et al. (1980) collected killifish (Fundulus spp.) from areas from known heavy metal contamination and areas of "less contamination" in Narragansett Bay, Rhode Island. Killifish from areas of high contamination contained copper levels of 3.9 ppm wet weight (converted from dry weight) and killifish from areas of "less contamination" contained 2.3 ppm wet weight. Based on this data, it appears that copper is below levels of concern in sea catfish.

Oysters and blue crabs contained much higher -concentrations of copper than the sea catfish. This is typical of these marine invertebrates. Experimental evidence indicates that decapod crustaceans, such as blue crabs, are able to regulate internal copper concentrations and avoid toxic levels (Rainbow 1985). Bivalves such as the oyster, on the other hand, may accumulate high levels of copper (Phillips and Russo 1978, Abbe and Sanders 1986).

Oysters from Copano Bay with a copper concentration of 280 ppm (dry weight) ranked tenth among 73 stations where oysters were collected in the 1986 National Status and Trends Program (NOAA 1987). The two highest concentrations during this investigation were 531 ppm and 416 ppm (converted to dry weight) , both from Copano Bay. Oysters from the other bays ranged from 117 to 295 ppm. Because oysters are capable of accumulating these high levels, apparently without harm to the organism, these levels are of concern primarily for human consumers. Roosenburg (1969) recommended maximum allowable copper level for human consumption of 500 ppm. One sample from Copano Bay exceeded this level. As with cadmium, the source of copper is currently unknown. Oil and gas exploration and production are again potential sources.

Lead

Lead was found above detection in 133 sediment samples. It was detected above quantification in all sea catfish and oyster samples, and in 62 of 65 blue crab samples. The lead levels in biota samples were generally low. The highest geometric mean was 0.19 ppm (wet weight) in sea catfish. The levels in blue crabs were slightly lower with a geometric mean of 0.10. Oysters contained the lowest concentrations, with a geometric mean of 0.07 ppm.

Lead is both a nonessential and a nonbeneficial element. Lead is toxic in most of its chemical forms and can bioaccumulate causing sublethal effects to

hematopoietic, vascular, nervous, renal and reproductive systems (Eisler 1988b). Despite its toxicity, few threshold levels have been established for lead in the tissues of aquatic organisms.

The geometric mean of 5.1 ppm lead in sediment is an indication that sediments of the study area are relatively uncontaminated. Harrison (1987) determined that the background lead level of soils in the vicinity of Corpus Christi, Texas, was 13.0 ppm. The maximum concentration in sediment in our study was 19.0 ppm.

The concentration of lead in sea catfish was low. This study's lead levels were slightly higher than those found for sea catfish in the Lower Laguna Madre and South Bay (Gamble et al. 1988) where the geometric mean was 0.09 ppm. Killifish collected by Custer et al. (1986) from areas of-known heavy metal contamination in Narragansett Bay, Rhode Island contained lead levels of about 2.5 ppm wet weight (converted from dry weight), and killifish from "less contaminated" areas had levels of about 0.3 ppm.

Although the levels of lead in blue crabs in this study were similar to the concentrations in blue crabs from the Lower Laguna Madre and South Bay, where lead ranged from 0.07 to 0.35 ppm, the significance of these levels is currently unknown. The levels of lead in oysters were relatively low compared to concentrations detected in mussels and oysters for the 1986 National Status and Trends Program (NOAA 1987).

Mercury

Only eight sediment samples were found to contain mercury above detection limits. All biota samples contained detectable levels of mercury. The geometric mean concentration in biota was highest in sea catfish (0.173 ppm wet weight), next highest in blue crabs (0.038 ppm), and lowest in oysters (0.008 ppm). The highest concentration of 0.591 ppm was detected in a blue crab sample from Lavaca Bay. Comparison of mercury levels in blue crabs from individual bays reveals that concentrations in blue crabs from Lavaca Bay were two to four times those from other bays.

Mercury concentrations in biota are of special concern because mercury can bioconcentrate in organisms and biomagnify through food chains, impacting fish, wildlife, and man (Eisler 1987b). Mercury does occur naturally, but it has no known biological function. Mercury concentrations below 0.5 ppm wet weight in tissues are generally accepted as levels typical of unpolluted environments (Abernathy and Culmbie 1977). The Food and Drug Administration's (FDA) action level is 1.0 ppm of methylmercury in edible portions. All biota samples, except one, were below the 0.5 ppm level. The one sample which exceeded this level was a blue crab sample from Lavaca Bay (blue crabs were the only biota collected from Lavaca Bay). The seven blue crab samples collected from Lavaca Bay contained the seven highest mercury concentrations in blue crabs.

Lavaca Bay has a history of elevated mercury levels associated with an aluminum processing plant. Initial sampling of Texas Bays in 1970 by the Texas Department of Health (TDH 1977) revealed elevated mercury levels only in oysters from Lavaca Bay. These findings led to a closure of shellfish harvesting in July 1970. Samples of finfish collected in 1976 also revealed elevated levels of mercury in some species: black drum (Pogonias cromis) averaged 2.18 ppm mercury (wet weight basis) and redfish (Scianops ocellata) averaged 5.65 ppm mercury. More recent sampling by the TDH show that mercury levels have declined in most species since 1976, but many samples remain elevated above the FDA action level. In April of 1988, the Texas Health Commissioner closed portions of Lavaca Bay to both recreational and commercial finfishing and crabbing.

Nickel

Nickel concentrations in sediment ranged from 1.0 ppm to 15.0 ppm in 187 samples. It was detected at low levels in all biota samples. In biota, oyster samples generally contained the highest levels (geometric mean = 0.27 ppm wet weight), blue crabs were the next highest with a geometric mean of 0.10 ppm, and sea catfish contained the lowest levels with a geometric mean of 0.05 ppm.

Apparently because of its low toxicity to humans, there is a lack of residue data on nickel for comparisons. In addition, nickel does not accumulate in aquatic organisms (Phillips and Russo 1978).

Comparison of sediment concentrations to the baseline for soils of the western U.S. (Wilson 1986) indicates that nickel is relatively low in sediments of the Aransas Bay Complex. Nickel concentrations in all biota samples were also low. The Panel on Nickel (1975) considered levels below 0.75 ppm (wet weight) nickel to be normal for aquatic organisms. All biota samples were below this level.

Selenium

Selenium was at detectable levels in 51 sediment samples. Virtually all samples were below 1 ppm, however one sample containing 5.10 ppm was noticeably higher. The concentrations in sea catfish averaged slightly higher than in blue crabs or oysters (geometric mean = 0.78 ppm wet weight). Selenium concentrations in blue crabs (geometric mean = 0.62 ppm) were generally higher than those in oysters (geometric mean = 0.38 ppm).

Selenium is an essential trace element. Impacts to animals may result from both selenium deficiency and selenium poisoning (Eisler, 1985b). Potential effects of high levels of selenium range from physical malformations during embryonic development to sterility and death (Lemly and Smith 1987).

The levels of selenium detected in sediments of the Aransas Bay Complex are relatively low and probably are indicative of the natural content of soils. Lemly and Smith (1987) state that soils rarely contain greater than 2 ppm selenium. All but one sample was below this level. This one sample was from St. Charles Bay and contained 5.10 ppm selenium. This appears to be an anomaly, since other samples from this bay are much lower.

Residue levels in all biota samples were below levels considered to be harmful. Baumann and May (1984) considered that selenium levels of 2 ppm (wet weight) or more in fish tissue may be indicative of concentrations that could cause toxic effects. All concentrations in sea catfish from this study were below this level (Maximum was 0.92 ppm wet weight). The concentrations in blue crabs and oysters are typical of selenium levels in marine invertebrates which are usually less than 2 ppm on a wet weight basis (Eisler 1985-b).

Zinc

Zinc is another essential micronutrient which at sufficient concentrations can result in lethal or sublethal effects. Marine fish and oysters have been noted for accumulating higher levels relative to freshwater organisms (Phillips and Russo 1978, Duke 1967). Sea catfish in this study contained the highest concentration of zinc (geometric mean of 146.9 ppm wet weight). Oysters contained the next highest concentrations with a geometric mean of 125.6 ppm. The geometric mean for zinc in blue crabs was 22.1 ppm. The geometric mean for zinc in sediments was 16.7 ppm, all but one sample contained zinc above detection limits.

The levels of zinc appear elevated in sea catfish when compared with zinc concentrations detected in fish from other studies. The geometric mean of zinc in sea catfish from this study (146.9 ppm wet weight) is nearly three times higher than the geometric mean for sea catfish from the Lower Laguna Madre and South Bay, Texas (Gamble et al. 1988). Custer et al. (1986) detected 40 ppm zinc (converted from dry weight) in killifish from a site considered highly contaminated with heavy metals in Narragansett Bay, Rhode Island. Although the zinc levels appear elevated, the biological significance of these levels in sea catfish is not known. These concentrations are well below the level of 1,000 ppm wet weight zinc used by Australia as a standard for sea foods (Talbot et al. 1985).

The data indicates that sea catfish are capable of concentrating zinc, since levels in other biota and sediments were not elevated. The levels in oysters can be compared with levels reported in the National Status and Trends Program for 73 oyster sampling stations along the Gulf and Atlantic coasts (NOAA 1987). The zinc concentrations in oysters from this study are below the median levels in the National Status and Trends Program. The zinc levels in sediment were also below the median when compared with the levels in sediment analyzed for the National Status and Trends Program (NOAA 1988).

Petroleum Hydrocarbons

All biota samples were analyzed for selected aliphatic and aromatic hydrocarbons (Table 1). Sediments were analyzed only for oil and grease. Eleven of the selected aliphatic hydrocarbons were detected in biota samples. Only three of the 18 selected aromatic hydrocarbons were found above detection limits. Detectable levels of oil and grease were associated with all sediment samples.

Oil and Grease In Sediment

Oil and grease is comprised of numerous natural and petroleum derived hydrocarbons, including fats, oils, and waxes of vegetable or animal origin. Oil and grease levels have been of concern to environmental agencies on the Texas coast because these levels are often reported for sediments which are proposed for dredging by the U.S. Army Corps of Engineers.

The geometric mean for oil and grease in sediments was 423 ppm (n=376). The lowest level detected was 17 ppm and the highest was 3886 ppm. Ninety-four percent of sediment samples contained oil and grease below 1,000 ppm, while 5.6 percent of the sediment samples contained oil and grease in the range of 1,000 to 2,000 ppm (Figure 6). Only two samples, both from Espiritu Santo Bay, contained levels greater than 2,000 ppm, these levels were 2,448 ppm and 3,886 ppm. Approximately 38 percent (n=8) of the samples above the 1,000 ppm levels occurred near oil and gas platforms and 31 percent (n=7) occurred near submerged pipelines. The sample from Espiritu Santo Bay containing the highest level of oil and grease was collected from a navigation channel leading from the Gulf Intracoastal Waterway to Matagorda Island (the Ferry Channel) . The sample with the second highest level of oil and grease was collected from this same navigation channel and adjacent to an oil platform.

It is difficult to accurately assess the significance of oil and grease in sediment. Few standards have been developed for judging the significance of oil and grease levels. Prater and Hoke (1980) used three ranges of oil and grease to describe the relative extent of sediment contamination: 1) levels less than 1,000 ppm are unpolluted, 2) levels ranging from 1,000 ppm to 2,000 ppm are moderately polluted, and 3) levels greater than 2,000 ppm are heavily polluted. Cain (1989) recently examined oil and grease levels in sediments in Galveston Bay and made recommendations based on the percent of oil and grease that was composed of polycyclic aromatic hydrocarbons (PAHs). Since PAHs are the component of greatest concern, this method is probably the most meaningful. PAHs were not determined for sediment samples for this study, however.

Aliphatic and Aromatic Hydrocarbons

Eleven of the 14 selected aliphatic hydrocarbons (alkanes) were found above detection limits in biota samples (Table 6). Alkanes were frequently detected

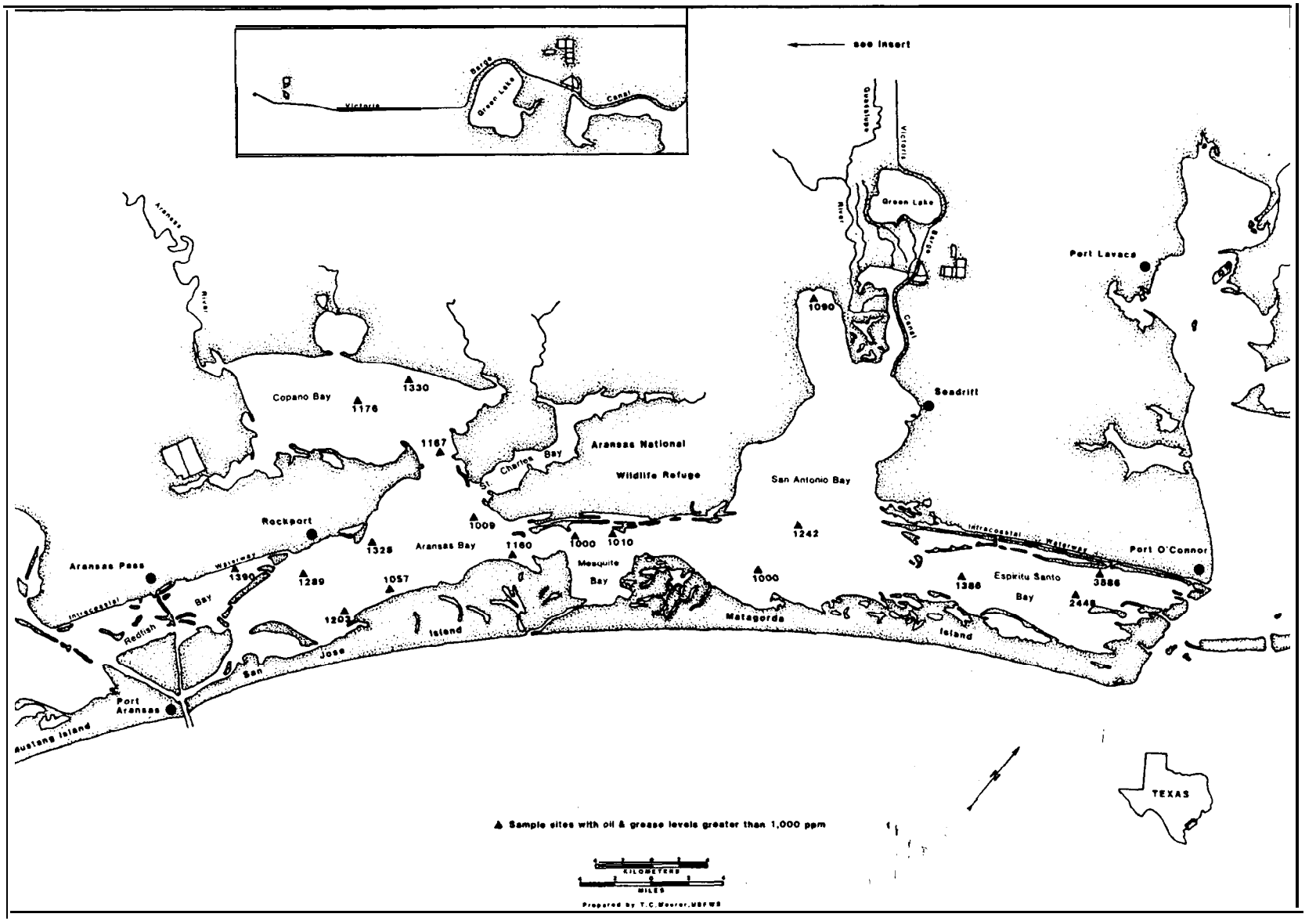

Figure 6. Location of sediment sample sites with oil and grease levels greater than 1000 ppm in the Aransas Bay Complex.

Table 6. Geometric means and ranges (ppm wet weight) of aliphatic hydrocarbons (alkanes) in biota from the Aransas Bay Complex, Texas, 1985-1986.

Chemical	Blue Crab n=65	Sea Catfish n=11	Eastern Oyster n=9
n - Tridecane	---[1] (0.03-0.05)[2] 5[3]	--- (.03) 1	BDL[4]
n - Tetradecane	--- (.03) 6	--- (0.03-0.04) 5	BDL
n - Pentadecane	0.11 (0.03-0.69) 62	0.18 (.04-.75) 11	--- (0.03-.04) 3
n - Hexadecane	--- (0.03-.08) 20	--- (0.04-.07) 5	BDL
n - Heptadecane	0.13 (0.03-1.20) 63	.41 (0.06-2.30) 11	.03 (0.03-0.04) 7
Pristane	0.05 (0.03-0.48) 54	0.08 (0.03-0.66) 9	BDL
n - Octadecane	--- (0.03-0.05) 3	--- (0.05-0.09) 5	BDL
Phytane	(0.03-0.08) 13	--- (0.05-0.06) 3	BDL
n - Nonadecane	(0.03-0.23) 7	--- (0.07-0.21) 4	BDL
n - Eicosane	--- (0.03) 1	BDL	BDL
Heneicosane	--- (0.03-0.17) 3	--- (0.03) 1	BDL

[1] Geometric means (Geometric mean calculated only for those with › 50% detection).
[2] Range in parenthesis
[3] Number of samples above detection
[4] BDL - Below detection limit

in blue crab and sea catfish samples. However, they were seldom above detection in oyster samples. The majority of alkanes were detected in fewer than 50 percent of samples. Only three alkanes (n-pentadecane, n-heptadecane and pristane) were detected in greater than 50 percent of biota samples. All alkanes were detected at relatively low levels. Polycyclic aromatic hydrocarbons (PAHs) were detected above quantification -limits in only two biota samples. Benzo (b) fluoranthrene was detected at 0.026 ppm (wet weight) in an oyster composite and chrysene, 1,2- benzanthracene, and benzo (b) fluoranthrene were detected at 0.051 ppm, 0.048 ppm, and 0.023 ppm, respectively, in a sea catfish sample.

Aliphatic hydrocarbons are a major component of petroleum products, (Sandmeyer 1981, National Academy of Sciences 1985). Armstrong et al. (1979) listed several alkanes found in crude oil at separator platforms in Trinity Bay, Texas. This included several of the selected alkanes investigated-in this study. These selected alkanes are also components of kerosene, jet fuels, and lubricating oils (Sandmeyer 1981).

Several alkanes (the odd-numbered carbon n-alkanes) are also produced by algae and phytoplankton (Blumer et al. 1971, Coates et al. 1986, D. Scalen, pers. comm.). In particular, n-pentadecane, n-heptadecane, n-nonadecane, and pristane have been noted as alkanes produced by marine algae (Shaw et al. 1986). Pristane is also a component of calanoid copepods and may be detected in fish that have fed on these copepods (Blumer et al. 1963, Blumer 1967). The higher odd-numbered carbon n-alkanes (those with 21 to 33 carbon atoms are produced by terrestrial plants (Shaw et al. 1986, National Academy of Sciences 1985).

A determination of the contribution from petroleum and biogenic sources is possible only on a relative basis. A predominance of odd-numbered carbon n-alkanes suggests a biogenic source (Sanders et al. 1980, National Academy of Sciences 1985). In petroleum hydrocarbons, there is no distinct preference for odd or even-numbered carbon n-alkanes, and the occurrence of phytane suggests a petroleum hydrocarbon source especially when the pristane to phytane ratio is less than one (National Academy of Science 1985).

Using these guidelines it appears that the majority of alkanes detected in this study were of biogenic origin. The three alkanes most frequently detected (n-pentadecane, n-heptadecane, and pristane) are usually associated with biogenic sources. Phytane was detected in 13 blue crab samples and three sea catfish samples, but phytane was detected at a higher concentration than pristane (i.e., the pristane to phytane ratio was less than one) in only one blue crab sample.

A large information base is developing for the PAHs. This is largely due to their toxicity and the fact that several are among the most potent carcinogens known to exist (Eisler 1987a). Like the aliphatic hydrocarbons, PAHs may also be biogenically produced by microorganisms, algae and macrophytes. A variety

of other sources contribute to aromatics in the environment. In aquatic environments, petroleum spillage is the major source of PAHs; other sources are atmospheric deposition (emissions from the burning of fossil fuels, refuse burning, grass fires), wastewater discharges and land surface runoff (Eisler 1987a).

Fish have been noted for containing unusually low levels of PAHs (Lawrence and Weber 1984, Baumann et al. 1988). This has been attributed to their ability to rapidly metabolize PAHs (Neff et al. 1976, Lawrence and Weber 1984, Niimi and Palazzo 1986). Crustaceans also have the enzymes necessary to metabolize PAHs (Statham et al. 1976). Bivalves, however, lack the necessary enzymes to metabolize PAHs, and therefore tend to accumulate these compounds upon exposure.

The one sea catfish sample that contained PAHs was collected from Espiritu Santo Bay (biota site 16). The analysis of sediments for oil and grease revealed that some of the highest oil and grease levels were detected in Espiritu Santo Bay. This bay has numerous oil and gas wells, and pipelines that carry these products. In addition, a variety of petroleum products are transported along the Gulf Intracoastal Waterway which traverses this bay. Because oil spillage is considered the major source of PAH's in aquatic environments, these appear to be possible sources of the PAH's detected in this sea catfish sample. The biological significance of the detected levels in this sea catfish sample is currently unknown.

One PAH compound, benzo (b) fluoranthrene, was detected in one of the oyster samples in this study. The concentration of 0.026 ppm (wet weight) is relatively low when compared with concentrations detected in mussels and oysters for the National Status and Trends Program (NOAA 1987). This sample was collected from San Antonio Bay (biota site 32) adjacent to the Victoria Barge Canal and the City of Seadrift. Several petrochemical industries and a coke treatment facility discharge industrial effluents into the Victoria Barge Canal and are potential sources of the PAH detected in this oyster sample.

Oil Or Hazardous Substance Spills

This study indicates that the Aransas Bay Complex is relatively free of serious contaminant problems. The most serious threat is from oil or hazardous substance spills that may occur in the GIWW or other navigation channels. A wide variety of such substances are shipped via barges on the GIWW including crude petroleum, diesel fuel, gasoline, jet fuel, kerosene, benzene, toluene, crude tar, tar and pitches, coke and petroleum coke, solvents, sulfuric acid, sodium hydroxide, acrylonitrile, and a variety of basic chemicals utilized by chemical industries (Garrett and Burke 1989).

The most crucial area is the land-locked portion (from False Liveoak Point to Dunham Island) of the GIWW that passes through whooping crane critical habitat. An oil or hazardous substance spill in this area could have disastrous environmental effects. A spill occurring from mid-October to mid-April could result in the loss of whooping cranes and also contaminate or deplete the food items of the cranes. A spill occurring-at any time of the year is likely to impact a variety of other bird life and estuarine organisms.

There are no easy solutions to this threat. The Corps of Engineers is currently reviewing alternatives for altering the route of the GIWW. These alternatives would likely reduce or eliminate the threat of spills to the land-locked section, but other significant environmental impacts accompany these alternatives and other portions of the refuge would still be open. to the threat of spills. At the very least, we should encourage the Corps of Engineers to examine the best available technology which could be used along the land-locked portion of the GIWW, to reduce the threat and impacts of oil or hazardous material spills. Such a study should examine safety measures that could be implemented and structural designs which would prevent oil or hazardous substances from washing into areas used by the whooping cranes.

SUMMARY

Organochlorine, PCB, trace element, and petroleum hydrocarbon contaminants were examined in biota from the Aransas Bay Complex, Texas (San Antonio and Aransas-Copano Bays). Trace elements and oil and grease levels were examined in the sediments of these bays. Because of the proximity -of Lavaca Bay to San Antonio Bay, blue crab samples were also collected there. This study was designed to provide baseline information on a variety of contaminants and to detect contaminant hot spots.

Fourteen organochlorine compounds were detected-in biota samples. The DDT family compounds (DDT, DDD and DDE) and the chlordane isomers (oxychlordane, cis-chlordane, trans-chlordane, cis-nonachlor, and trans-nonachlor) were the compounds most frequently detected. All organochlorines were-detected at relatively low levels. PCB's were not found above detection limits in biota samples.

The levels of DDT family compounds are lower than those detected in past studies. All levels of total DDT were below the 1,000 ppb level recommended for the protection of aquatic life. The data indicates that wintering whooping cranes have been exposed to very low levels of total DDT. These levels are not likely to have affected their reproductive success. Highly piscivorous birds, such as the brown pelican, have been exposed to slightly higher levels of these compounds. These levels are likely to have caused a slight degree of eggshell thinning, but not enough to result in egg loss.

The level of total chlordane (the sum of all chlordane isomers) in all biota samples was below the 100 ppb level recommended for the protection of aquatic life. The levels of other organochlorines were also below levels considered biologically significant.

Trace elements were detected at low levels in most biota samples. However, cadmium and copper were detected at elevated levels in oyster samples in Copano Bay. These levels in oysters are of concern mainly for human consumers. This also may indicate that other bivalves in Copano Bay may have elevated levels of cadmium and copper. This could have implications for whooping cranes which feed on a variety of clams.

Elevated mercury levels were detected in blue crabs collected from Lavaca Bay. Lavaca Bay has a history of elevated mercury levels associated with an aluminum processing plant. Recent sampling by the Texas Department of Health shows that mercury levels have declined in most species sampled since 1976, but many samples remain elevated above the FDA action level. Portions of Lavaca Bay are currently closed to both recreational and commercial finfishing and crabbing.

The majority (94 percent) of oil and grease levels in sediment samples were below 1,000 ppm. Of the samples exceeding the 1,000 ppm level 69 percent were

collected in the vicinity of oil and gas platforms or submerged pipelines. Although these higher oil and grease levels provide a relative index of contamination they only indicate areas that may require further study. Examination of sediment PAH levels is recommended for areas with elevated oil and grease levels in sediment.

The examination of aliphatic and aromatic levels in biota reveals that most biota were relatively free of petroleum hydrocarbons. Polycyclic aromatic hydrocarbons were detected in only one fish sample and one oyster sample. Three PAHs were detected in a fish sample from Espiritu Santo Bay where the highest oil and grease levels were detected. One PAH was detected in an oyster sample collected in San Antonio Bay near the Victoria Barge Canal. Several petrochemical industries and a coke treatment facility discharge their effluents into the Victoria Barge Canal.

In general, this study indicates that, of the contaminants examined, most were below levels of concern. The most serious threat is from oil or hazardous substance spills that may occur in the portion of the GIWW that passes through the Aransas National Wildlife Refuge. A spill occurring in this section of the GIWW from mid-October to mid-April could result in the loss of whooping cranes and contaminate or deplete food items of the cranes.

RECOMMENDED STUDIES

The results of this study show that four contaminants were detected at elevated levels: cadmium and copper were found at elevated levels in oysters in Copano Bay; mercury was elevated in blue crabs from Lavaca Bay: and the data indicates that petroleum hydrocarbons may be a problem in Espiritu Santo Bay and the northern portion of San Antonio Bay transected by the Victoria Barge Canal. In order to fully assess the significance of these elevated levels more definitive studies will be necessary. Therefore, we recommend the following investigations:

1. A more intensive study of sediments and biota is needed in order to determine the nature of elevated cadmium and copper in oysters. It is recommended that oysters and other bivalves be included in such a study. Inclusion of bivalve species that are preferred foods of the whooping crane is also recommended.

2. A more intensive study is needed in Lavaca Bay to determine the role that maintenance dredging plays in periodically exposing the local fauna to elevated mercury.

3. A more intensive study of PAHs in sediment and biota in Espiritu Santo Bay and the north side of San Antonio Bay transected by the Victoria Barge Canal is needed.

4. It is recommended that the Corps of Engineers examine the best available technology, including structural design and safety practices, which could be implemented along the land-locked section of the GIWW to reduce the threat and impacts of oil or hazardous material spills.

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