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A Survey of Chemical and Biological Structure in Three Florida Bayou-Estuaries

GLENN L. BUTTS AND MICHAEL A. LEWIS

Detailed information on the benthic macroinvertebrate community composition is unavailable for most Gulf of Mexico near-coastal areas. In response, structural and functional characteristics of this biota were determined, in conjunction with sediment chemical quality and acute toxicity, for three urbanized bayous. Sediment chemical contamination in the bayous was common. Numerical sediment quality assessment guidelines were exceeded at 13 of the 16 sampling stations for as many as six analytes. However, the results of whole sediment toxicity tests conducted with the benthic invertebrates *Mysidopsis bahia* (epifaunal) and *Ampelisca abdita* (infaunal) indicated that 14 of the 16 sediments were not acutely toxic. The benthic macroinvertebrate composition was indicative of that for organically enriched sediments, and the quality was spatially distinct and sometimes increased seaward. The percent of the fauna indicative of organic enrichment ranged from 14 to 100% for the 16 sampling stations. Pollution-tolerant infaunal species such as the polychaetous annelids *Streblospio benedicti* and *Mediomastus ambiseta* were dominant. The Shannon-Wiener diversity index values ranged from 1.0 to 3.8. The quality of the macroinvertebrate communities paralleled the results for sediment chemical quality and particle size distribution more so than those for acute toxicity. It was obvious that an integrated chemical and biological assessment was needed to characterize the environmental condition of the sediments in these urbanized coastal habitats.

Florida has the second largest coastline in the United States, and 60% of the state's residents live within 10 miles of the coastal zone (Florida Center for Public Management, 1995). As a consequence, ~1045 square miles of Florida estuaries do not fully support their designated use—that is, recreation, propagation, and maintenance of a well-balanced benthic macrofaunal community structure—because of urban development (Hand and Paulic, 1992). However, this area of impact may be underestimated, because it is based primarily on measurements of surface water chemical quality and, to a lesser extent, on analysis of planktonic biota. The extent, magnitude, and biological impact of sediment contamination in most Florida estuaries is not well understood and has not been a factor commonly considered in their environmental analysis.

Urban or residential bayous are relatively common near populated areas in the Gulf of Mexico region. Their ecological condition, often unknown, is of great public interest because of their recreational and scenic value. This is the case for Bayous Texar, Chico, and Grande, which are small, shallow estuaries located adjacent to Pensacola Bay, Florida's fifth largest estuarine system. The chemical quality of the bayous is impacted primarily by stormwater runoff that originates from the extensive urban and industrial development in their watersheds (Northwest Florida Water Management District, 1992, 1997; Lewis et al., 2000). However, the biological impact of the chemical contamination is not well understood, particularly when based on benthic macroinvertebrate community structure. This information is important because this community lives in contact with bottom sediments, is relatively immobile, and is considered to be an excellent indicator of environmental contamination (Burton, 1991). The primary objective of this study was to describe this fauna in detail for the first time for the bayous.

The use of a combination of chemical analysis, toxicity testing, and benthic community analysis is considered the most effective way to determine sediment quality (Traunspurger and Drews, 1996). A weight-of-evidence approach based on these assessment methods has been used for sediments collected from the Great Lakes (Krantzberg and Boyd, 1992), the Atlantic Coast (McKee et al., 1997), and the Pacific Coast (Chapman et al., 1987; Anderson et al., 1989; Becker et al., 1989). An additional objective of this study was to confirm the usefulness of this triad approach for these small residential Florida estuaries where it has not been previously applied and reported.

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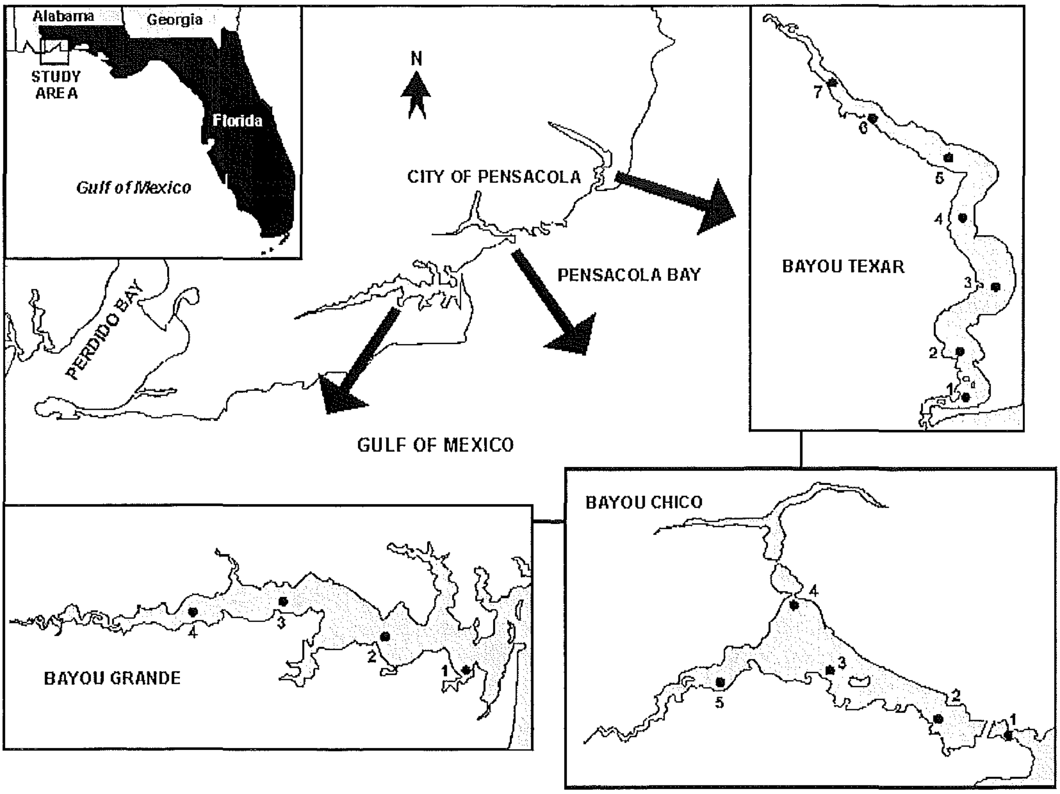

Fig. 1. Location of the three mesohaline bayous in Northwest Florida (Escambia Co.).

Methods

Study area and sampling stations.—The sediments were collected during 1993–1994 from three mesohaline bayous located near Pensacola, Florida (Fig. 1). The bayous are relatively small (surface area range, 0.4–1.5 mi^2) and shallow (mean depth range, 2–3 m), and their chemical quality is affected by the urbanization and industrial development in their watersheds (Northwest Florida Water Management District, 1990; Florida Department of Environmental Protection, 1998).

Sediments were collected from seven sites in Bayou Texar (June 1993), four in Bayou Grande (June 1993), and five in Bayou Chico (May 1994). Replicate sediment samples were collected at each site to a maximum depth of ~10 cm by use of a stainless steel grab sampler (volume, 2.1 L). The replicate samples were combined, homogenized, and split for chemical and toxicological analysis. The benthos were removed on site from two additional samples collected from the same site by use of a 500-μm mesh stainless steel sieve. Specimens were stored in 10% neutral buffered formalin or 70% ethanol that contained rose bengal prior to their identification.

Chemical analysis.—Bottom water salinity was determined by use of a refractometer (Leica Inc., Buffalo, NY), and sediment particle size distribution was determined by use of standard techniques (ASTM, 1993; American Public Health Association et al., 1995). Concentrations of trace metals, organochloride pesticides, PCBs (polychlorbiphenyls), and PAHs (polycyclic aromatic hydrocarbons) listed in Table 1 were determined for each sediment sample according to USEPA techniques (1997). The sediments for metal analysis were digested in nitric acid by use of a microwave oven and then analyzed by use of a Jarell-Ash Atomcomp Series 800 ICP (Fisher Scientific Co., Franklin, MA). The method detection limits for the metals were between 0.7 and 1.5 μg/g dry weight. Mercury (total) was analyzed with a PS200 automated mercury analyzer (Leeman Labs, Inc., Hudson, NH) by use of cold-vapor atomic absorption analysis with tin as a reductant. The method detection limit was 0.2 ng/g dry weight.

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TABLE 1. Sediment chemical quality and sediment particle size distribution in Bayous Texar, Chico, and Grande. BD, below method detection limit and ND, not detected.

Bayou and station	Total chlorinated pesticides	Total PAHs	Total PCBs	Total metals	Trace metal						Percentage	
					Cd	Cr	Cu	Ni	Pb	Zn	Sand	Silt/Clay
Texar												
1	BD	BD	BD	6.4	BD	1.25	2.3	BD	BD	2.9	98	2
2	BD	BD	BD	2.7	BD	BD	BD	BD	BD	2.7	99	1
3	BD	BD	BD	5.8	BD	1.2	BD	BD	BD	4.6	98	2
4	16.2	5764.7	39.2	308.1	BD	26.5	25.9	6.7	70.0	179.0	7	93
5	25.6	1400.5	17.9	527.1	0.8	48.2	45.0	12.9	96.0	325.0	7	93
6	60.9	2872.4	36.6	722.5	1.4	30.8	88.6	8.7	145.0	548.0	7	93
7	91.0	2244.7	43.5	1345.6	2.7	32.7	338.0	11.2	125.0	833.0	2	98
Chico												
1	72.5	ND	62.6	253.1	BD	15.0	39.7	3.4	36.0	159.0	80	20
2	83.9	ND	68.3	864.6	6.9	20.6	119.0	11.0	48.1	665.0	68	32
3	73.9	ND	104.2	677.8	1.1	25.1	110.0	10.4	48.2	483.0	50	50
4	3.0	ND	8.2	757.5	1.4	30.0	106.1	10.7	71.3	538.0	31	69
5	92.3	ND	64.5	1068.4	2.3	39.9	137.2	21.0	257.0	611.0	16	84
Grande												
1	23.2	6010.0	91.5	764.6	10.5	397.0	56.0	8.1	141.0	152.0	80	20
2	10.9	28.6	4.4	44.8	BD	5.4	2.6	24.0	ND	12.8	4	96
3	27.1	1443.9	57.9	222.2	2.0	57.5	17.7	6.4	55.0	83.6	49	51
4	3.7	142.2	5.9	89.7	BD	25.6	8.7	3.3	17.0	35.1	61	39

Concentrations of chlorinated pesticides, PCBs, and PAHs in the sediments were solvent extracted (acetone/acetonitrile) for 30 min. The elutriates were analyzed by use of a PH-5890 Series II gas chromatograph (Hewlett Packard Corp., Palo Alto, CA). The analysis used multilevel calibration and internal standards for peak identification and quantitation. The method detection limits were 2 ng/g dry weight. Standards, blanks, and spike surrogates were used for all inorganic and organic analytical determinations.

The measured concentrations of the inorganic and organic analytes were compared with effects-based, sediment quality assessment guidelines proposed for Florida coastal areas (Florida Department of Environmental Protection, 1994). The specific numerical guidelines used in this comparison were the threshold effects level (TEL) and the probable effects level (PEL), and their description and significance has been described elsewhere (FDEP, 1994; McDonald, 1994).

Whole sediment acute toxicity.—Whole sediment bioassays were conducted with the epibenthic mysid, *Mysidopsis bahia,* and the infaunal amphipod, *Ampelisca abdita.* These solid-phase tests were conducted with sediments stored <2 wk and followed standardized procedures (ASTM, 1993; USEPA, 1994, 1996). The tests with mysids were conducted with sediments collected in June 1993 (Bayous Texar and Grande) and May 1994 (Bayou Chico). Thirty juvenile mysids were exposed to each sediment sample; five in each of six replicates. *A. abdita* were exposed to sediments collected from Bayous Texar and Grande during September. Ten organisms were exposed in each of 10 replicates for each sediment sample. Survival of the organisms was recorded after 7 (*mysids*) and 10 d of exposure (*Ampelisca*). Sediments that exhibited mortality of ≥24% (control-corrected) were considered toxic (Swartz et al., 1995; Long et al., 1998). A reference sediment collected from Perdido Bay, FL was included in the bioassays. The nontoxic nature of this sediment has been confirmed in numerous acute bioassays conducted at the USEPA Gulf Ecology Division Laboratory, Gulf Breeze, FL (unpubl. data).

Macroinvertebrate community composition.—Macroinvertebrates were identified in replicate sediment samples collected from each of the 16 stations. Identifications were made to the lowest possible taxa by use of regional taxonomic keys such as those of Day (1973), Fauchald (1977), Cooley (1978), Heard (1982), Goeke and Heard (1983), Williams (1984), and Foster (1989). Slide mounts were used to identify polychaetous annelids of the family *Nereidae*. A Leica Wild M 3 Z stereo zoom microscope was used to identify whole specimens, and a Nikon Labophot phase-contrast compound microscope was used to examine parapodia from nereid polychaetes.

Several taxonomic structural and functional measurements of the benthic community were used as indicators of sediment quality. These included taxa richness (number of species) and species diversity. Species diversity was calculated by use of the Shannon-Wiener diversity index (Shannon and Weaver, 1949) which is the most widely used index of its type, including in regulatory Florida investigations. The validity of this index improves with sample size and, consequently, values for sediments with <100 individuals need to be reviewed with caution. A thorough description of this index and its relevance has been presented elsewhere (Washington, 1984).

The percentage of pollution sensitive taxa was used to indicate community integrity, stability, and health. This determination was based on information reported by Farrell (1992) and the North Carolina Department of Environmental, Health and Natural Resources (1997). The polychaete/bivalve ratio and the number of predators, and epibenthic, and infaunal species were used also as indicators of sediment quality. Undesirable shifts in community structure are characterized by increased dominance of burrowing infaunal forms, decreased dominance of epifaunal forms and predators, and an increase in the polychaete/bivalve ratio. Epifaunal taxa are generally considered sensitive to environmental stress and include mysid shrimp, amphipods, and many crustaceans. In contrast, infaunal forms such as oligochaetes and species of the polychaete families *Spionidae* and *Capitellidae* are considered pollution tolerant (Farrell, 1992).

Statistical analysis.—This study was intended as a baseline survey, and only a limited number of samples were collected for the determinations of water quality, toxicity, and macroinvertebrate community analysis. Therefore, a detailed site-specific statistical analysis is not possible. However, to provide some insight, the structural parameters of the macroinvertebrate community were combined for all sites located within a bayou and compared among bayous by use of a one-way analysis of variance followed by post hoc analysis. All assumptions were met for this analysis. In addition, Pearson correlation coefficients (r) were calculated to determine the relationship between the Shannon-Wiener diversity index values and sediment particle size and bottom water salinity. All statistical analyses were conducted with the use of SAS/STAT (SAS Institute, 1989) at a significance level of 0.05.

Results

Chemical quality and particle size distribution.—There were considerable spatial differences in sediment chemical quality and particle size in all bayous, most noticeably in Bayou Texar (Table 1). Sediment chemical contamination progressively increased in this bayou with increasing distance from Pensacola Bay. This can be seen for most organic and inorganic analytes. Furthermore, the increasing degree of contamination paralleled the increasing percentage of clay/silt fraction. Sediments collected from those stations located nearer to Pensacola Bay (Stations 1–3), which were relatively uncontaminated, contained 1 or 2% silt/clay relative to 93–98% silt/clay for the contaminated sediments at Stations 4–7. Spatial differences in the chemical quality of the sediments in Bayou Chico followed a trend similar to that in Bayou Texar for many analytes. Several trace metal concentrations and the silt/clay fraction increased away from Pensacola Bay. In contrast, there was no consistent seaward pattern in the magnitude of the sediment contamination in Bayou Grande. Sediment chemical quality in this bayou was similar more at Stations 1 and 3 than that at Stations 2 and 4, which were also alike. Particle size distribution of the sediments was more heterogenous in this bayou, and no spatial trend was apparent.

The total number of sediment quality assessment guidelines (SQAGs) exceeded at each of the 16 sampling stations ranged from 0 to 6 (Table 2). As many as eight different TEL and six PEL guidelines were exceeded. No numerical guidelines were exceeded in the sand-dominated sediments located in Bayou Texar (Stations 1–3), but up to five TEL and as many as four PEL guidelines were exceeded elsewhere in the bayou. One to two TEL guidelines and as many as three PEL guidelines, all for divalent metals, were exceeded in Bayou Chico at the five sampling sites. A maximum of four TEL and two PEL guidelines were exceeded for sediments collected in Bayou Grande; however, no guidelines were exceeded at Station 4.

TABLE 2. Number of numerical SQAGs proposed for Florida coastal areas exceeded in the three bayous.

Bayou and station	SQAGs[a] ≥TEL < PEL	SQAGs[a] ≥PEL
Texar		
1	0	0
2	0	0
3	0	0
4	Zinc, copper, lead, total PCBs, total PAHs	0
5	Cadmium, copper, lead	Zinc
6	Cadmium, copper, total PCBs, total PAHs	Lead, zinc
7	Cadmium, total PCBs	Total PAHs, zinc, lead, copper
Chico		
1	Copper	Lead, zinc
2	Cadmium	Copper, lead, zinc
3	Cadmium	Copper, lead, zinc
4	Cadmium, copper	Lead, zinc
5	Cadmium, nickel	Copper, lead, zinc
Grande		
1	Total PCBs, total PAHs, zinc, copper	Cadmium, chromium
2	Nickel	Lead
3	Cadmium, chromium, lead, total PCBs	0
4	0	0

[a] See Florida Department of Environmental Protection (1994) for description.

Whole sediment toxicity.—Acute toxicity was uncommon (Tables 3–5). Survival of *M. bahia* after 7 d of exposure to the 16 sediment samples ranged from 3 to 100% (Bayou Texar), 93 to 100% (Bayou Grande), and 83 to 100% (Bayou Chico). The survival of *A. abdita* was between 6 and 98% (Bayou Texar) and 13 and 95% (Bayou Grande). Survival of these species after exposure to the reference sediment ranged from 90 to 100% (mysid) and from 88 to 100% (*Ampelisca*). Sediments collected from 2 of the 16 stations sampled in this study exhibited acute toxicity. Survival of *M. bahia* and *A. abdita* was 3% and 6%, respectively, after exposure to sediments collected from Station 7 in Bayou Texar. Survival of *A. abdita* was 13% after exposure to sediment collected from Station 1 in Bayou Grande, which constituted the 100% survival for mysids after their exposure to the same sediment.

The comparability of the toxicity results to sediment chemical quality, as indicated by the number of SQAG values exceeded, was site-specific (Table 6). The sediment acute toxicity results paralleled the number of guidelines exceeded at 6 of the 16 stations. Two of these six

TABLE 3. Comparison of macroinvertebrate community composition, whole sediment toxicity, and SQAGs in Bayou Texar. Values for Stations 1, 2, and 3 are for May, and the others are for June. Structural community characteristics are based on combined results for two replicate grab samples.

Sampling station	No. of samples	No. of individuals	Diversity index[a]	Percentage: Organic indicators	Percentage: Epifaunal taxa	Percentage: Infaunal taxa	Percentage: Predators	Polychaete/bivalves	Invertebrate survival (%)	SQAGs exceeded: ≥TEL <PEL	SQAGs exceeded: ≥PEL
1	14	67	2.6	25.3	56.7	38.8	4.5	25.4	100	0	0
2	13	43	3.2	37.2	9.3	86.0	4.7	53.5	100	0	0
3	20	63	3.8	14.3	19.0	79.5	8.0	66.8	97 (96)[b]	0	0
4	10	167	1.0	92.2	0.6	99.4	2.4	97.0	100 (97)	5	0
5	4	17	NC[c]	88.2	0	100	0	88.2	100 (98)	3	1
6	5	36	1.5	94.5	0	100	0	83.3	100	4	2
7	2	2	NC	NC	NC	NC	NC	NC	3 (6)	2	4

[a] Shannon and Weaver (1949).
[b] Value in parentheses for *Ampelisca abdita*.
[c] NC, not calculable because of low species and individual numbers.

TABLE 4. Comparison of benthic macroinvertebrate composition, whole sediment toxicity, and proposed SQAGs for Bayou Chico. Values are for sediment collected during May 1994. Structural community characteristics are based on combined results for two replicate grab samples.

Sampling station	No. of species	No. of individuals	Diversity index[a]	Percentage: Organic indicators	Epifaunal taxa	Infaunal taxa	Predators	Polychaete/ bivalve	Invertebrate survival (%)	SQAGs exceeded: ≥TEL <PEL	≥PEL
1	16	98	3.0	57	5	87	5	57	100	1	2
2	1	30	NC[b]	100	0	100	0	100	90	1	3
3	5	37	NC	92	0	100	0	97	90	1	3
4	21	158	3.3	58	6	73	8	87	83	2	2
5	3	42	NC	95	0	95	5	100	97	2	3

[a] Shannon and Weaver (1949).
[b] NC, not calculable because of low species and individual numbers.

sediments (Texar Station 7 and Grande Station 1) were acutely toxic to at least one of the invertebrate test species, and a total of six numerical chemical guidelines were exceeded for each of these sediments. No guideline values were exceeded, and no acute toxicity (control adjusted) was observed at the remaining four stations (Texar Stations 1–3 and Grande Station 4). A total of six SQAG guidelines or as many as five TEL and three PEL guidelines were exceeded for the remaining 10 sediment samples; however, invertebrate survival was high and ranged from 83 to 100% (*M. bahia*) and 95 to 98% (*A. abdita*) in these same sediments.

Macroinvertebrate community composition.—Bayou Texar: The quality of the macroinvertebrate community increased noticeably seaward in this bayou (Table 3). The biota at Stations 4–7 located near the freshwater source was characterized by low numbers of species and individuals, burrowing infaunal taxa (range, 99–100%), and pollution tolerant taxa (88.2–94.5% of total). The two more abundant species were the pollution tolerant polychaetous annelids *Mediomastus ambiseta* and *Streblospio benedicti,* which comprised a combined 66.7% of the taxa in these clay/silt dominated sediments. The number of predators was the least in these sediments (range, 0–2.4%), the polychaete/bivalve ratios were the highest (range, 88.3–97.0%), and the Shannon-Wiener diversity index values were <1.5.

In contrast to the above, the macroinvertebrate fauna at Stations 1–3 was more diverse. These sand-dominated sediments contained 19 species of epifaunal organisms, which comprised 9.3–56.7% of the total individuals collected. Species number ranged from 13 to 20, and the total number of individuals was between 43 and 67. The number of predators was greater, the polychaete/bivalve ratios were lower, and the diversity index values greater (range, 2.6–3.2) than for the silt/clay-dominated sediments at Stations 4–7.

The decrease in quality of the macroinvertebrate fauna in Bayou Texar paralleled the decline in sediment chemical quality (Tables 3 and 6). A total of four to six SQAGs were exceeded in those sediments (Stations 4–7) for which the Shannon-Wiener diversity index values were the least (≤1.5) and where organic indicator organisms predominated (mean, 91.6 ± 1; SD, 3.2%). In contrast, sediments for which no SQAGs were exceeded (Stations 1–

TABLE 5. Comparison of benthic macroinvertebrate composition, whole sediment toxicity, and SQAGs in Bayou Grande. Values for sediment collected during June 1993. Structural community characteristics are based on combined results for two replicate grab samples. ND, not determined.

Sampling station	No. of species	No. of individuals	Diversity index[a]	Percent: Organic indicators	Epifaunal taxa	Infaunal taxa	Predators	Polychaete/ bivalves	Invertebrate survival (%)	SQAGs exceeded: ≥TEL <PEL	≥PEL
1	17	106	2.0	81.1	7.4	88.4	3.7	90.3	100 (13)[b]	4	2
2	9	101	1.7	88.1	4.9	91.1	1.0	91.1	93 (95)	1	1
3	9	352	1.2	89.2	7.1	92.9	0	92.7	100 (ND)	4	0
4	7	103	1.2	92.3	0	98.9	0.9	98.9	100 (94)	0	0

[a] Shannon and Weaver (1949).
[b] Values in parentheses are for *A. abdita.*

TABLE 6. Comparison of SQAGs, whole sediment acute toxicity, and the Shannon-Weaver diversity index value.

Bayou and station	SQAGs			Invertebrate survival[a]	Diversity index[b]
	≥TEL <PEL	≥PEL	Total		
Texar					
1	0	0	0	100	2.6
2	0	0	0	100	3.2
3	0	0	0	97 (96)	3.8
4	5	0	5	100 (97)	1.0
5	3	1	4	100 (98)	—[c]
6	4	2	6	100	1.5
7	2	4	6	3 (6)	—
Chico					
1	1	2	3	100	3.0
2	1	3	4	90	—
3	1	3	4	90	—
4	2	2	4	83	3.3
5	2	3	5	97	—
Grande					
1	4	2	6	100 (13)	2.0
2	1	1	2	93 (95)	1.7
3	4	0	4	100	1.2
4	0	0	0	100 (94)	1.2

[a] Mysids and, when available, *A. abdita* (in parentheses).
[b] Shannon and Weaver (1949).
[c] Not calculable because of low numbers of species and individuals.

3) were characterized by higher diversity index values (mean, 3.2 ± 0.6) and contained a lower percentage of organic indicator organisms (mean, 25.6 ± 11.5%).

It is obvious that benthic invertebrates in Bayou Texar were more diverse and dense in the sand-dominated sediments comprised largely of sand (Tables 1 and 3). The Shannon-Wiener diversity index values were between 2.6 and 3.8 in sediments containing 98–99% sand, relative to index values of ≤1.5 in sediments comprised of ≤7% sand.

Bayou Chico: Infaunal organisms comprised 73–100% of the taxa in this bayou, depending on the sampling location (Table 4). Approximately 57–100% of the taxa were indicative of organic enrichment, and the dominant species at most stations were *S. benedicti* and *M. ambiseta*. Spatial differences in community composition were obvious, but no consistent trend seaward and no relationship to sediment particle size was obvious. Diversity and density were too low at Stations 2, 3, and 5 to calculate diversity index values. Species number averaged (3.0 ± 1; SD, 2.0) and mean individual number was 36.3 (±6.0). Organic indicator organisms comprised between 92% and 100% of the total taxa. No predator species were identified at two of these three stations, and the polychaete/bivalve ratios ranged between 97 and 100%. In contrast, a total of 16–21 species and 98–158 individuals were collected from Stations 1 and 4. The Shannon-Wiener diversity index values were 3.0 and 3.3, respectively. The percentage of organic indicator organisms was lower in these sediments (57% and 58%), and, unlike elsewhere, epifaunal species were identified (5% and 6%).

The relationship of benthic invertebrate community composition and chemical quality as indicators of sediment condition was not obvious (Tables 4 and 6). Sediments in which the benthos were the least diverse (Stations 2, 3, and 5) contained contaminants that exceeded a total of either four or five SQAGs, including three PEL guidelines. However, a total of three and four SQAGs, which included two PEL guidelines, were exceeded for those sediments (Stations 1 and 4) that contained the more diverse macroinvertebrate benthos.

Sediment particle size distribution had no observable effect on the Shannon-Wiener diversity index values (Tables 1 and 4). Two of the three sediments (Stations 2 and 3), where diversity index values could not be calculated because of low species number (50% and 68%), consisted primarily of sand, but the other sediment (Station 5) was composed of 84% silt/clay. Diversity index values of ≥3.0 occurred for benthos obtained from sediments either dominated by sand (80%, Station 1) or silt/clay (69%, Station 4).

Bayou Grande: The majority of the benthic macroinvertebrates in Bayou Grande were indicators of organic enrichment (mean, 87.7 ±1; SD, 4.7%) (Table 5). Only eight epifaunal species were identified, which comprised, on average, 4.9% (±3.4%) of the identified taxa. The benthic community was dominated, although to a lesser extent, by the pollution-tolerant *S. benedicti* (16.9% of total taxa) and *M. ambiseta* (16.3% of total taxa).

Several structural parameters of the benthic macrovertebrate community decreased slightly with increasing distance from Pensacola Bay (Table 5). For example, species numbers decreased from 17 to 7 and the Shannon-Wiener diversity index values from 2.0 to 1.2. Furthermore, the percentage of epifaunal species decreased from 7.4 to 0%, whereas the infaunal taxa increased from 88.4 to 98.9%.

The number of SQAGs exceeded and the structural characteristics of the benthos are

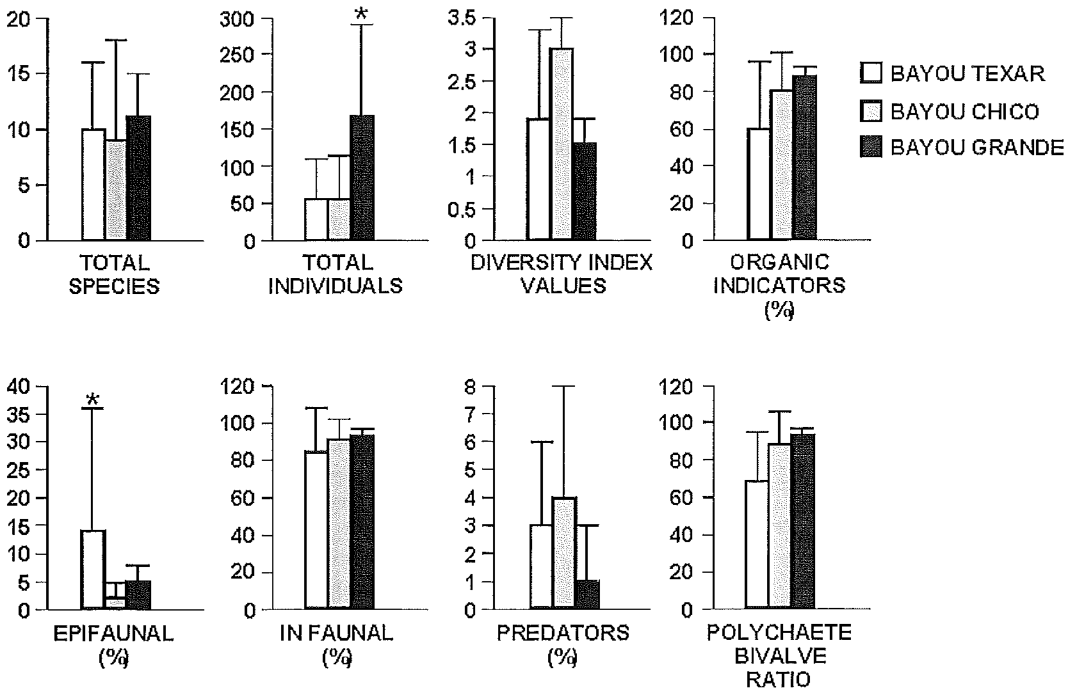

Fig. 2. Comparison of several structural and functional characteristics of the benthic macro invertebrate community in the three bayous. Values represent mean and SD for the multiple sampling stations in each bayou. The sampling periods were June (Bayous Texar and Grande) and May (Bayou Chico). *Significant difference ($P < 0.05$).

compared in Table 5 for each station. The highest diversity index value of 2.0 and the greatest number of individuals occurred at Station 1, where a total of six SQAGs (four TEL and two PEL) were exceeded. Conversely, the benthos at Station 4 was characterized by the fewest species (seven) and a lower diversity index value (1.2), but no SQAGs were exceeded.

The highest diversity index value (2.0) occurred in the most sand-dominated sediment (80%, Station 1). Benthic invertebrates in the most silt/clay-dominated sediment (96%, Station 2) had a diversity index value of 1.7. The diversity index values were the least (1.2) for sediments (Stations 3 and 4) characterized by a more diverse particle size distribution. The average sand and silt/clay content was 55 and 45%, respectively.

Discussion

The primary objective of this survey was to describe the benthic macroinvertebrate communities in the three almost adjacent, urbanized bayous. The benthic macrofauna in the bayous was dominated by infaunal taxa (range, 84–93% of total taxa), comprised largely of pollution-tolerant polychaete species such as *S. benedicti* and *M. ambiseta*. Only 2–14% of the organisms were pollution–sensitive, epifaunal forms. These results would be expected for shallow near-coastal areas that receive organic-laden storm-water runoff from commercial and residential areas, including seepage from poorly maintained domestic septic systems.

The macroinvertebrate communities in the three bayous were similar (Fig. 2). Most parameters were similar ($P < 0.05$) when averaged for all stations in each bayou. The exceptions were the greater density in Bayou Grande and the greater number of epifaunal species in Bayou Texar ($P < 0.05$).

A comparison of the community composition results of this study to those reported elsewhere for the bayous is limited by the lack of published data. Previous studies have focused on investigating water quality in most cases (USEPA, 1976; Young et al., 1988; Florida Northwest Florida Management District, 1997; Florida Department of Environmental Protection, 1998). Published descriptions of the macroinvertebrate fauna have been limited to Bayou Texar and then only described in general terms (Moshiri et al., 1978; Stone et al., 1991). Simultaneous evaluations of sediment chemical quality, toxicity, and benthic community composition have not been reported for these bayous. However, sediment toxicity evaluations conducted in conjunction with sediment chemical quality analysis have occurred (Long et al., 1997; Lewis et al., 2000). Toxicity was prevalent in these previous studies, which contrasts the results of this study. This is attributable to the different types of toxicity tests and test species used in these previous investigations.

The ability of the three assessment techniques used in this study to determine sediment quality has been discussed for each bayou elsewhere. In general terms, declines in the Shannon-Wiener diversity index values paralleled those in sediment chemical quality more so than whole-sediment acute toxicity (Table 6). This result was more noticeable in Bayou Texar and, to a lesser extent, in Bayou Grande. The lack of congruity between acute toxicity and the other assessment techniques, however, needs to be considered in the context that there is no consensus on the suite of species needed to characterize sediment toxicity and the results of sediment bioassays are often species- and media-specific (Transpurger and Drews, 1996). This effect, as stated earlier, has been reported for sediments in these bayous.

Physical and chemical factors other than anthropogenic chemicals in sediments can affect macroinvertebrate community composition such as sediment particle size and salinity. The only significant correlation between particle size and the taxonomic structural characteristics of the invertebrate benthic community occurred in Bayou Texar, where the diversity index values decreased with increasing silt/clay content ($r = -0.91$, $P = 0.004$). Bottom salinity at the various sampling stations ranged from 12 to 22 ppt (Bayou Texar), 16 to 31 ppt (Bayou Chico), and 13 to 23 ppt (Bayou Grande). The diversity index values increased significantly with increasing salinity in Bayous Texar and Chico ($P < 0.05$; $r = 0.85$ and 0.97, respectively). In Bayou Grande, there was no significant correlation ($r = 0.85$, $P = 0.15$).

In summary, the macroinvertebrate communities in the bayous were indicative of contaminated sediments at most sampling stations. The determination of community composition was important in the analysis of sediment quality in these bayous, because chemical analysis and acute toxicity assessment alone or even in combination would have provided an incomplete perspective.

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