Bull. Environ. Contam. Toxicol. (1992) 49:922–928

Environmental Contamination and Toxicology

Effects of Contaminants of Macrobenthic Communities in the Upper Calcasieu Estuary, Louisiana

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The upper Calcasieu Estuary near Lake Charles, Louisiana was investigated recently due to contamination from petrochemical industries. Studies showed contamination of surface sediments by metals (Ramelow et al. 1989; Mueller et al. 1989) and organics (Murray and Beck 1990). Concentrations of contaminants were especially high in Bayou D'Inde and Bayou Verdine, and a human health advisory was recently posted in the estuary as a result. Samples of commercial fish, shrimp, and crabs indicated that certain contaminants were found in edible fish and shellfish (Pereira et al. 1988; Ramelow et al. 1989; Murray et al. In Press).

The importance of macrobenthic (small, bottom-dwelling) invertebrate communities to commercial fisheries is well established in the literature. Benthos may directly affect biogeochemical processes in the sediments and provide a coupling between contaminants and the food chain. The macrobenthic invertebrates of the upper Calcasieu Estuary represent much of the biomass at the base of the detritus food chain, and may provide the key to understanding the magnitude of impact that contaminants have on the food chain. Gaston and Nasci (1988) and Gaston et al. (1988) described the benthic trophic structure of the Calcasieu Estuary, and thus established a mechanism to relate benthic communities to contaminants. The purpose of this study was to investigate the relationship between the macrobenthic trophic structure and selected contaminants of the upper estuary. The discussion centers around specific impacts such as urban and industrial discharge, and illustrates the effects of contaminants on trophic structure of benthic-invertebrate communities.

MATERIALS AND METHODS

The study area was the upper Calcasieu Estuary near Lake Charles, Louisiana (Figure 1). The estuary extends 52 km from a saltwater barrier near Lake Charles to the Gulf of Mexico at Cameron, Louisiana. This study centered on Bayou D'Inde, Contraband Bayou, and Bayou Verdine, which all empty into the Calcasieu River near Lake Charles. All sampling sites in these low-salinity bayous were in areas of muddy sediments (70 - 95% silt and clay), with anoxic (reducing) conditions less than 2 cm below the sediment surface. Dissolved oxygen (DO) values of bottom waters during summer months often were below 2 mg L^{-1}; DO values generally exceeded 10 mg L^{-1} during winter. Contraband Bayou is an oligohaline bayou that winds through the city of Lake Charles and

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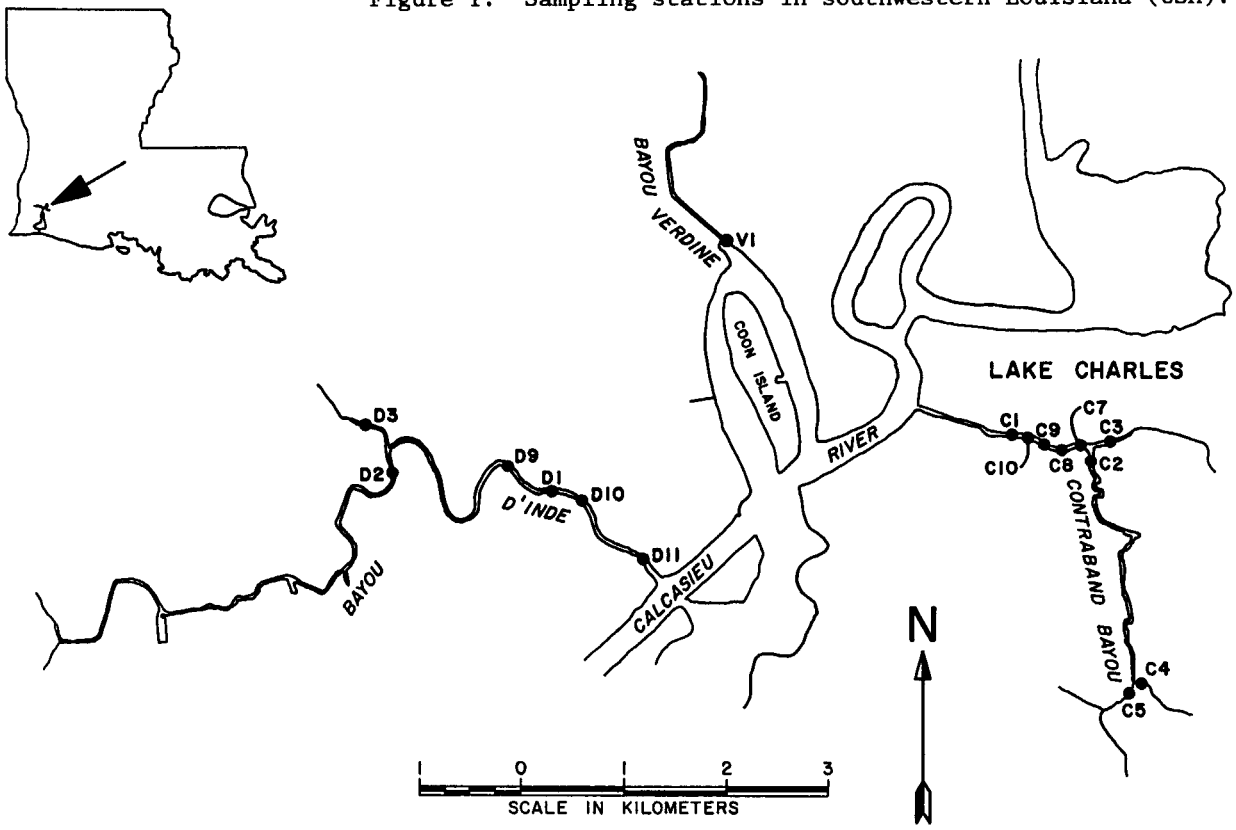
Figure 1. Sampling stations in southwestern Louisiana (USA).



receives waste water from a treatment facility (POTW) near its confluence with the Calcasieu River. Bayou D'Inde has been channeled; it receives industrial effluent from several petrochemical industries and waste water from the cities of Sulfur, Westlake, and Maplewood. Bayou Verdine enters the Calcasieu River approximately 2 km north of Bayou D'Inde, and also receives effluent from several industries. All of these bayous typically have a 2 ppt increase in salinity from the surface to bottom, and instantaneous flow that is flood directed at the bottom, with current strength varying according to the tidal phase. Additional habitat descriptions were provided by Gaston and Nasci (1988) and Gaston et al. (1988).

Benthic sampling was conducted from November 1983 through December 1984. Macrobenthic communities were sampled with a 15 X 15 cm stainless steel pole-mounted Ekman grab. Benthic samples were collected in Contraband Bayou, Bayou D'Inde, and Bayou Verdine on a stratified-random scheme (see Gaston and Nasci 1988). Specimens were preserved in the field in 7% buffered formalin and returned to the laboratory for identification and enumeration. Hydrographic data were collected on the water surface and bottom with a Hydrolab Series 4000 to measure pH, conductivity, dissolved oxygen, and temperature.

Data on distribution of metals were provided by Beck et al. (1987) and Ramelow et al. (1989). They collected sediments with an Ekman grab at the same sites listed above, and found surficial sediments with background levels of 0.60 mg kg^{-1} As, 0.3 to 1.4 mg kg^{-1} Cd, 10 mg kg^{-1} Cu, 15 mg kg^{-1} Pb, < 0.05 mg kg^{-1} Hg, and 40 mg kg^{-1} Zn. Concentrations of organic pollutants in shrimp, collected at the same sites, were provided by Murray and Beck (1989, 1990). They found shrimp containing chlorinated compounds throughout the estuary, and especially high concentrations occurred in the bayous.

Benthic species were classified for analyses of trophic groups using methods of Gaston (1987). Feeding categories of the study area included carnivores, herbivores, omnivores, and detritivores. Detritivores dominated the study area; therefore they were subdivided into surface-deposit feeders, subsurface-deposit feeders (mostly burrowers), and suspension feeders (mostly tube dwellers). Habitats were characterized by ratios of feeding groups. These methods allowed investigation of the effects of contaminants on functional-feeding biology of the communities.

Statistical analyses for this study included community analyses using analysis of variance and Duncan's multiple range tests to test for differences among station groups and among feeding groups. Pearson's correlation coefficients (Sokal and Rohlf, 1981) were calculated for number of individuals of dominant species and total species in the community each season versus concentrations of metals (copper, lead, chromium, mercury, zinc, and cadmium) in sediments.

RESULTS AND DISCUSSION

Bayous of the upper Calcasieu Estuary supported only sparse populations of benthic organisms, and was inhabited by lower densities of benthos than the middle or lower estuary (Gaston and Nasci 1988). Benthic assemblages of the upper estuary were numerically dominated by deposit feeders, and the most abundant species of the upper estuary were two surface-deposit feeding polychaetes (Streblospio benedicti and Hobsonia florida) (Table)

Table 1. Mean densities of numerically dominant macrobenthic taxa in three bayous of the Calcasieu Estuary during 1983 and 1984.

Taxa	Density (number per $0.5m^{-2}$)
CONTRABAND BAYOU	
Hobsonia florida (Polychaeta; SDF[1])	93.8
Tubificidae (Oligochaeta; SsDF)	89.0
Streblospio benedicti (Polychaeta; SDF/SuF)	48.6
Polydora socialis (Polychaeta; SDF/SuF)	11.4
Polydora ligni (Polychaeta; SDF/SuF)	11.2
Corophium louisianum (Amphipoda; SuF)	4.7
BAYOU D'INDE	
Tubificidae (Oligochaeta; SsDF)	67.6
Hobsonia florida (Polychaeta; SDF)	54.4
Laeonereis culveri (Polychaeta; SDF/SsDF)	15.6
Nereis succinea (Polychaeta; SDF)	8.2
Mediomastus californiensis (Polychaeta; SsDF)	6.4
BAYOU VERDINE	
Streblospio benedicti (Polychaeta; SDF/SuF)	110.4
Laeonereis culveri (Polychaeta; SDF/SsDF)	46.6
Polydora ligni (Polychaeta; SDF/SuF)	39.6
Nereis succinea (Polychaeta; SDF)	14.4
Rangia cuneata (Mollusca; SuF)	13.2

[1] SDF = Surface-deposit feeder; SsDF = subsurface-deposit feeder; SuF = suspension feeder.

Both species are early colonizers in the succession of benthic communities. Their dominance resulted in greater proportions of surface-deposit feeders in the upper estuary than elsewhere (Gaston and Nasci 1988). The imbalance of feeding groups in the upper estuary indicated that communities in that area were not at equilibrium, and that some type of disturbance or stress likely limited further succession of the benthic community.

Contraband Bayou supported sparse to moderate densities of benthic organisms (Table 1). Contraband Bayou communities were numerically dominated by S. benedicti and H. florida during the fall and winter (1983-1984), but were replaced by subsurface-feeding tubificid and naidid oligochaetes by summer of 1984. These oligochaetes were mostly juveniles that lived near the sediment surface, unlike deep-burrowing forms. Most of the sites sampled in Contraband Bayou supported similar densities of macrofauna, except sites nearest the POTW that were devoid of macrofauna. Sediments at the outfall were putrid and appeared anoxic. They also contained elevated levels of Cu, Zn (Ramelow et al. 1989), and Hg (Mueller et al. 1989). During summer months the dissolved oxygen level at the sediment-water interface of the sites was generally below 2 mg L^{-1} (summer DO ranges: Contraband Bayou, 0.2 - 3.4; Bayou D'Inde, 0.1 - 2.2; Bayou Verdine, 0.3 - 4.0).

Table 2. Pearsons correlations between numbers of individuals and concentrations of metals in sediments of bayous in the Calcasieu Estuary, Louisiana during winter and spring 1984.

	D'Inde n[1] = 8	Verdine n = 6	Contraband n = 9
Cu	-.544	-.618	-.681*
Pb	-.649*	-.680	-.580*
Cr	-.558	-.014	-.676*
Hg	-.742**	-.568	-.615*
Zn	-.460	-.628	-.634*
Cd	-.764**	-.359	-.601*

[1] Number of sites is indicated by n. A single asterisk indicates $P \leq 0.05$; a double asterisk indicates $P \leq 0.01$).

The benthic community of Contraband Bayou (species number and number of individuals) and presence of heavy metals generally were inversely related (Pearson's Correlations) (Table 2). Total numbers of individuals were negatively correlated with concentrations of all metals. A negative correlation indicated that the abundance of macrofauna and metal concentrations were inversely proportional (macrofauna abundance decreased significantly as concentrations of metals increased, and vice versa). Species number and metals were also inversely related during winter and spring 1984, but the correlations were not as strong, which is typical of such relationships when species numbers are low. Although negative correlations do not necessarily indicate a direct relationship between metal concentrations and benthos, the relationship is strongly implied from these results.

Benthic assemblages in Bayou D'Inde were so depauperate that relationships between contaminants and individual taxa were not as closely correlated as in Contraband Bayou. Often, grab samples in Bayou D'Inde failed to collect any benthic organisms. The most abundant taxa collected there were H. florida and tubificid oligochaetes (Table 1). No other species occurred in mean abundance over 50 individuals $0.5\ m^{-2}$.

The numbers and diversity of benthic organisms in Bayou D'Inde fell below those of most low-salinity estuarine habitats, and densities of macrofauna were below those of non-POTW sites in Contraband Bayou. Previous research in Bayou D'Inde indicated very high concentrations of Hg (Mueller et al. 1989), Pb, Cu, and Cr (Ramelow et al. 1989). There were inverse relationships between benthic communities and sediment metals in Bayou D'Inde (Table 2). Numbers of macrofauna were related especially to concentrations of Pb, Hg and Cd. These relationships suggested that benthic assemblages in Bayou D'Inde were adversely affected by metals or factors that covary with metals in the sediments. The pattern occurred at a time when populations of H. florida were declining and tubificid oligochaetes were increasing in abundance (Gaston and Nasci 1988), perhaps indicating that tubificids were more tolerant of the conditions than H. florida.

Macrobenthic assemblages were sampled at the mouth of Bayou Verdine. Barges and pipelines prevented access to the remainder of the bayou. Bayou Verdine was contaminated by Hg (Mueller et al. 1989) and several other metal contaminants (Ramelow et al.

1989). The mouth of Bayou Verdine may be generally characterized as dominated by a mixed assemblage of surface-feeding polychaetes: Streblospio benedicti, Laeonereis culveri, and Polydora ligni. These species were all early-colonizing species, perhaps indicative of constant disturbance to the area. Their populations fluctuated widely, which confounded analyses of relationships between contaminants and densities of benthos (Table 2).

Generally, the bayous of the upper Calcasieu Estuary supported a poor mix of macrobenthic trophic groups (Gaston and Nasci 1988), as indicated by the dominance of surface-deposit feeders and shallow-burrowing subsurface-deposit feeders (Table 1). Deposit feeders were often the only trophic group collected, which is indicative of the importance of the detritus food chain to macrofauna of the area. Since surface-dwelling benthic species may be less susceptible to sediment contaminants than subsurface-deposit feeders (burrowers) or suspension feeders (mostly tube builders), the dominance by surface-deposit feeders may be indicative of the effects of contaminants on the benthic community and the harsh environment below the sediment surface.

Carnivorous macrobenthos, which also generally feed at the sediment surface, were poorly represented in the upper estuary, and seldom represented over 3% of the fauna, perhaps indicative of the low densities of prey in the area (Gaston and Nasci 1988; Gaston et al. 1988). Omnivorous species, which include juvenile crabs and shrimp, were even less abundant than carnivores, and represented only 1% of the benthic macrofauna.

Contaminants were not likely the only factors affecting benthos of these bayous. Several alternative hypotheses could be proposed to explain the sparse populations of benthos in the study area. The most feasible may be that (1) food was limiting to the populations of benthos; therefore, there was selection for certain taxa, such as surface-deposit feeders, or (2) harsh environmental conditions eliminated the taxa. High levels of TOC and high productivity of phytoplankton and zooplankton in the upper Calcasieu Estuary (DeRouen and Stevenson 1987) probably invalidate the first hypothesis. Organic matter was so high that low dissolved oxygen occurred periodically. Low dissolved oxygen values and widely fluctuating salinities support the second hypothesis. Generally, however, subsurface-deposit feeders (burrowers) are better adapted to survive harsh DO and salinity conditions than surface-deposit feeders (Gaston et al. 1985); these bayous were dominated by surface-deposit feeders, and supported few burrowers, and no deep-burrowing taxa.

One cannot dismiss the relationships between the high concentrations of metals and benthos. The benthic organisms certainly appeared to be impacted by contaminants in the upper estuary, especially in Contraband Bayou, Bayou D'Inde, and perhaps the mouth of Bayou Verdine. In summary, many of the macrofaunal communities of the upper Calcasieu Estuary were a complex of species that lived in an area contaminated by industrial and municipal discharges. The area was stressed by low dissolved oxygen and concentrations of several metal contaminants. The trophic structure of the benthic community indicated effects on the macrofaunal organisms, including diminished populations and depleted trophic groups.

Acknowledgments. This research was part of the Ecosystem Analysis of the Calcasieu River/Lake Complex (CALECO), funded by the U. S. Department of Energy and through a subcontract from the Louisiana Department of Wildlife and Fisheries. I am grateful to M.

Walther, D. Chestnut, and M.C. Hager for help with sampling and laboratory analyses.

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Received September 1, 1991; accepted June 30, 1992.