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STATISTICAL SUMMARY: EMAP-ESTUARIES LOUISIANIAN PROVINCE - 1993

by

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DISCLAIMER

This report represents data from a single year of field operations of the Environmental Monitoring and Assessment Program (EMAP). Because the probability-based scientific design used by the EMAP necessitates multiple years of sampling, there may be significant levels of uncertainty associated with some of these data. This uncertainty will decrease as the full power of the approach is realized by the collection of data over several years. Similarly, temporal changes and trends cannot be reported, as these require multiple years of observation. Please note that this report contains data from research studies in only one biogeographic region (Louisianian Province) collected in a short index period (July-August) during a single year (1993). Appropriate precautions should be exercised when using this information for policy, regulatory or legislative purposes.

PREFACE

This document is the third annual statistical summary for the Louisianian Province of the Estuaries component of the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program for estuaries (EMAP-E).

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ACKNOWLEDGMENTS

A large geographically extensive monitoring program such as EMAP in the Louisianian Province requires the interaction, coordination and cooperation of hundreds of individuals working together to complete the 1993 Demonstration. Space does not permit the individual citation of all who participated in the 1993 effort. We would like to to thank everyone who has participated in the success of the Louisianian Province and specifically acknowledge the following:

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EXECUTIVE OVERVIEW

STATUS OF THE CONDITION OF LOUISIANIAN PROVINCE ESTUARIES –1993

This statistical summary of the ecological condition of the estuarine resources is based on the results of the 1993 Louisianian Province Demonstration Project. The population of estuarine resources within the Louisianian Province consists of all estuarine areas located along the coastline of the Gulf of Mexico between, and including, the Rio Grande, TX, and Anclote Anchorage, FL.

Estuarine areas are defined as the saline, tidal ecosystems characterized by harbors, sounds, bays, and embayments bounded by barrier islands (seaward boundary) or surrounded by land with a restricted confluence with Gulf of Mexico and the portions of tidal rivers having a detectable tide (> 2.5 cm). These resources have been classified into three estuarine types:

- Large estuaries (surface area > 250 km^2, aspect (length/mean width) < 18)
- Large tidal rivers (surface area > 250 km^2, aspect > 18)
- Small estuaries and tidal rivers (2 km^2 < surface area < 250 km^2)

The Environmental Monitoring and Assessment Program (EMAP) is a national program initiated by EPA and integrating the efforts of several federal agencies to evaluate the status and trends of the ecological resources of the United States. EMAP-Estuaries (EMAP-E) is a part of EMAP organized to evaluate the status and trends of the estuarine resources of the United States. The Louisianian Province represents a single biogeographic area of the country corresponding to the Gulf of Mexico area. The Louisianian Province Demonstration Project was conducted during the summer of 1993 (July-August) using a probability-based sampling design to evaluate the condition of the estuarine resources in this geographic region. This probabilistic sampling design makes it possible to estimate the proportion or amount of the total area in the Louisianian Province (25,725 km^2) having defined environmental conditions, based on sampling only a portion of the province.

One hundred fifty-four sites between Anclote Anchorage, FL, and the Rio Grande, TX, were sampled during the eight-week sampling period (Fig. 1). A total of 19 sites were not sampled in 1993. Nine sites were not sampled due to inadequate water depth for sampling (i.e., < 1 m). Ten sites in the Mississippi River were not sampled due to strong water flow from the 1993 flood. Thus, based on the 1993 sampling design, 6.6% of the total estuarine area in the Louisianian Province could not be sampled with the present sampling plan. The bulk of this

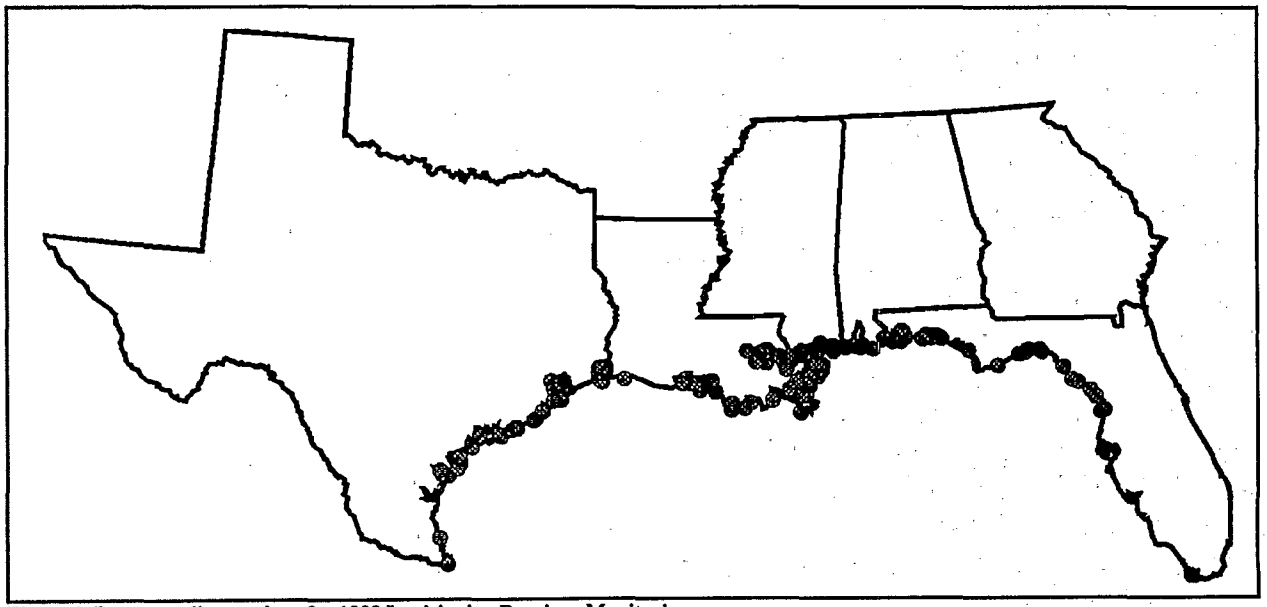


Figure 1. Base sampling stations for 1993 Louisianian Province Monitoring.

"unsampleable" area occurred in the shoreline areas of large estuaries where the average depth is < 1 m. Of the remaining sites, 96 locations represented probability-based sampling for the province and were used for the class and province estimates produced in this report. Thirty-nine sites were collected to provide estimates of variance, local enhancements of spatial scale for Sabine Lake, TX, and Choctawahatchee Bay, FL, and long-term trend estimation.

A series of indicators that are representative of the overall condition of estuarine resources were measured at each site. These indicators were designed to address three major attributes of concern: 1) estuarine biotic integrity, 2) societal values related to public use of estuarine resources, and 3) pollutant exposure, or the environmental conditions under which biota live.

The use of specific guidance referred to in the text as "criteria" does not infer the existance of established regulatory limits.

BIOTIC INTEGRITY

The condition of biological resources in the Louisianian Province was assessed using two indicators: one that measured the condition of estuarine benthos (bottom dwelling organisms) and one that measured the condition of fish communities. The benthic and fish indicators incorporated measures of species composition, abundance, and health to evaluate the condition of the benthic and fish assemblages. Indices were determined from the combined 1991 and 1992 data to represent a combination of ecological measurements for each assemblage that best discriminate between good and poor environmental conditions. These indices represent EMAP-E's attempt to reduce dozens of indicators into a simple, interpretive value that has a high level of discriminatory power between good and poor environmental conditions. The indices were developed separately for fish and benthos using

information from regional reference sites and sites with known pollution exposure. The indices have been partially validated, but additional years of information will be required for complete validation; therefore, assessments based on these indices should be considered preliminary.

Benthic organisms were used as an indicator because previous studies suggested that they are sensitive to pollution exposure (Pearson and Rosenberg 1978, Boesch and Rosenberg 1981). They also integrate responses to exposure over relatively long periods of time. One reason for their sensitivity to pollutant exposure is that benthic organisms live in and on the sediments, a medium that accumulates environmental contaminants over time (Schubel and Carter 1984, Nixon et al. 1986). Their relative immobility also prevents benthic organisms from avoiding pollution exposure and environmental disturbance. A preliminary benthic index for the Louisianian Province was developed in 1991 (Engle et. al. 1993).

Preliminary estimates based on the 1993 Louisianian Province Demonstration indicate that 37±11% (95% C.I.) of the estuarine resources in the province had benthic resources characterized by lower than expected benthic diversity and low numbers of indicator species. Of the 25,725 km^2 comprising the estuaries of the Louisianian Province, about 9500 km^2 were ecologically degraded. For the benthic index, degraded conditions were defined as an index value < 4.0.

Although EMAP-E's primary objective is to describe status and trends at the province level, estimates can also be generated for subpopulations. The EMAP sampling design defined three classes of estuarine resources: large estuaries, large tidal rivers, and small estuarine resources. These classes were defined because estuaries of different sizes may show markedly different responses to anthropogenic impacts.

The incidence of degraded benthic resources was dissimilar among the three classes of estuaries sampled during 1993. Forty-eight percent (±26%) of small estuarine resources were degraded on an areal basis and large estuaries had only 34±12% of their area represented by degraded benthos (Fig. 2). However, while the proportion of area degraded in the small estuarine resources classes was high, the total area of degraded benthic resources in large

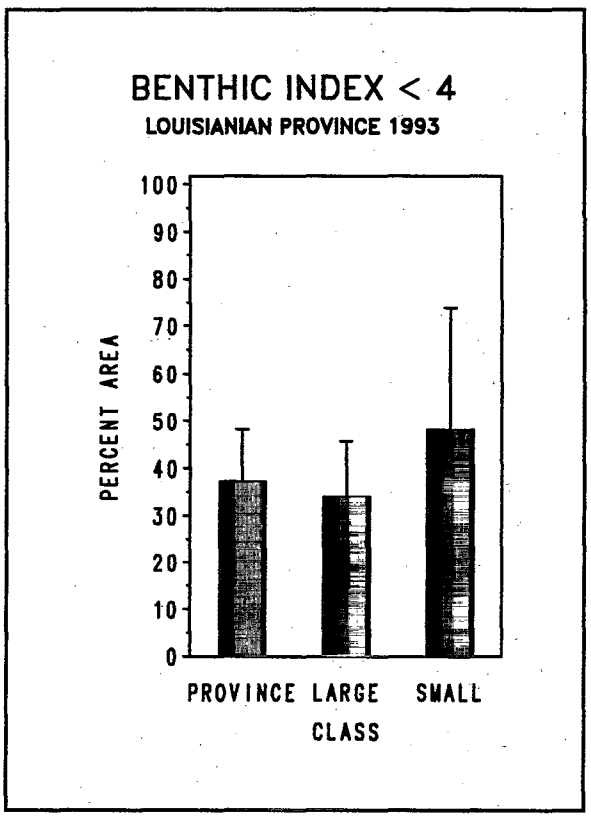


Figure 2. Percent of area having benthic index value < 4.0 for large estuaries (large), small estuaries (small), and the entire province, with 95% confidence interval.

estuaries was about 6200 km^2 as compared with 2700 km^2 for small estuaries.

HUMAN USE

Although the major objective of EMAP-E is to describe the status of estuarine resources using indicators of ecological condition, certain characteristics of estuaries, valued by society, may not be reflected by these indicators. We have included three indicators of perceptual condition in our assessment: incidence of marine debris, clarity of water, and contaminant levels in edible fish flesh. Data were collected during the 1993 Louisianian Province Demonstration to estimate the areal extent of estuaries having trash and turbid waters. Measurements were taken to estimate the proportion of fish populations of selected ecological, recreational, and commercial fish species having unacceptable levels of contaminants.

Observations concerning marine debris are important because debris has multiple deleterious effects on estuarine biota (entanglement and ingestion), can economically affect tourist areas (loss of tourists, beach clean-up costs), and contributes to the public perception of the general environmental condition of estuaries (Ross et al. 1991). It is estimated that marine debris was present at 10%±6% of the estuarine area in the Louisianian Province. This accumulates to over 2700 km^2 of estuarine bottom having identifiable marine debris in the Louisianian Province. No trash was identified as medical or hospital waste. Proportion of area having marine debris was higher in the small estuaries 13.5%, while 9.6% of the area of large estuaries had trash (Fig. 3).

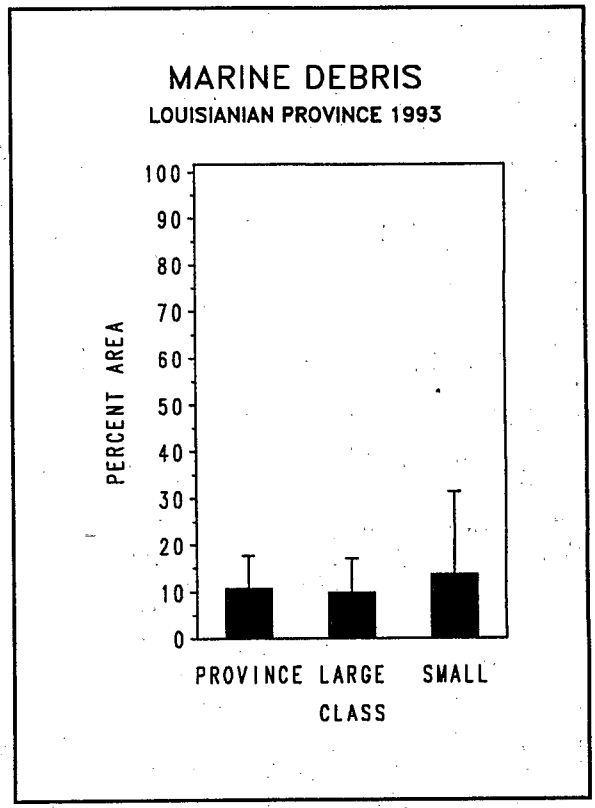


Figure 3. Percent of area having marine debris present for large estuaries (large), small estuaries (small), and the Louisianian Province, with 95% confidence interval.

Clear waters are valued by society and contribute to the maintenance of healthy and productive ecosystems. Water clarity was estimated using light transmission data as a comparison of incident light at the surface and reduced light at a depth of one meter. Water visibility of 10% at one meter was used to represent poor visibility (i.e., visibility of < 1 ft). Approximately 17.8±8% of the province had waters with visibility of < 10%. Clarity was much poorer in small estuaries (22.1±18%) than in large tidal estauries (16.4±9%) (Fig. 4).

Contaminant levels in edible fish tissue are perceived by the public as a negative quality for estuarine waters even if the concentrations are below levels that could have harmful effects.

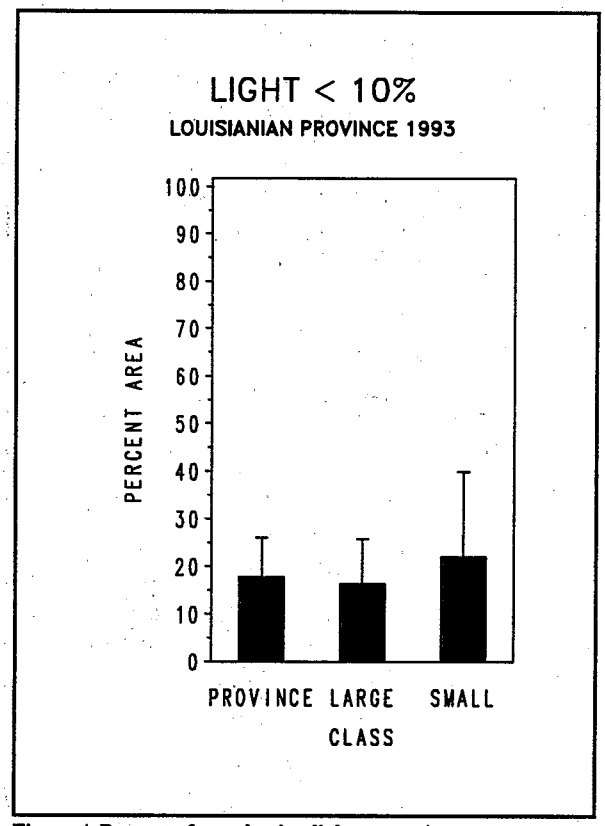


Figure 4. Percent of area having light transmittance at one meter depth at < 10% of incident light for large estuaries (large), small estuaries (small), and the Louisianian Province.

EMAP-E has compiled contaminant levels of pesticides, heavy metals, and polycyclic chlorinated biphenyls (PCBs) in edible fish tissues for three species groups: Atlantic croaker (*Micropogonias undulatus*), commercial shrimps (*Penaeus aztecus* and *Penaeus setiferus*), and marine catfish (*Arius felis*, *Bagre marinus*, and *Ictalurus furcatus*). The analysis done for tissue contaminants differs from those previously discussed in that the results refer to populations of organisms rather than areal extent in estuaries.

In general, contaminant concentrations in fish and shellfish were low with the exception of some heavy metals (arsenic, copper, mercury, and selenium) (Tables 1-3). Concentrations of pesticides and PCBs measured in brown and white shrimp tissue did not exceed existing FDA or international criteria (USFDA 1982, 1984; Nauen 1983). Criteria levels were exceeded by 9% of the shrimp sampled for concentrations of arsenic, copper, and mercury (Table 1).

Atlantic croaker is a recreationally and commercially important fish in the Louisianian Province. Concentrations of all chlorinated pesticides and PCBs were below FDA criteria. Arsenic concentrations exceeding 2.0 ppm (International criteria) were found in 5% of the croaker population (Table 2). Criteria for lead (0.5 ppm) and selenium (1.0 ppm) were exceeded by 2% of the population. Concentrations of chromium and copper with criteria values of 1 ppm and 15 ppm, respectively, were exceeded by 1% of the croaker population.

Marine catfish represent a minor recreational fishery in the Louisianian Province. Because their feeding habits bring them in direct contact with sediments, catfish were analyzed to examine the concentration of contaminants in their flesh. This category included sea cats (hardheads), gafftopsail catfish, and blue catfish. As was seen with croaker, catfish flesh contained concentrations of chlorinated pesticides and PCBs well within established criteria. Catfish contained elevated levels of arsenic (62% of samples exceeding 2 ppm). Lead concentrations exceeded 0.5 ppm in 5% of the catfish populations. Mercury and cadmium exceeded 1 ppm in 1% of the catfish populations (Table 3).

Overall, the number of contaminants seen in fish and shellfish exceeding the FDA action limits

Contaminant	Observed Range	Criterion[1]	Proportion Exceeding Criterion
Pesticides (ng/g wwt)			
DDD	ND	5000	0%
DDE	0-2.4	5000	0%
DDT	0-2.2	5000	0%
Aldrin	0-4.8	300	0%
Chlordane	ND	300	0%
Dieldrin	ND	300	0%
Endosulfan	0-3.2	NA[2]	U[3]
Endrin	0-0.0	300	0%
Heptachlor	0-8.0	300	0%
Heptachlor Epoxide	0-2.5	300	0%
Hexachlorobenzene	0-4.5	200	0%
Lindane	0-0.0	200	0%
Mirex	0-0.0	100	0%
Toxaphene	0-0.0	5000	0%
Trans-Nonachlor	0-1.5	NA	U
PCBs (ng/g wwt)			
21 Congeners	0-12.7	500	0%
Total PCBs	0-14.6	2000	0%
Heavy Metals (µg/g wwt)			
Aluminum	2.6-56.2	NA	U
Arsenic	0.18-4.1	2	9%
Cadmium	0-0.2	0.5	0%
Chromium	0.1-0.3	1	0%
Copper	5.9-18.3	15	9%
Lead	0-0.1	0.5	0%
Mercury	0-1.02	1	9%
Nickel	0.03-0.18	NA	U
Selenium	0.03-0.07	1	4%
Silver	0-0.05	NA	U
Tin	0-0	NA	U
Zinc	14.3-18.7	60	0%

[1] Criteria were selected from FDA established limits for pesticides and PCBs (USFDA 1982, 1984) except hexachlorobenzene and lindane which are based on Swedish limits (Nauen 1983); no FDA limits exist for metals other than mercury; metals criteria reflect means of international limits (Nauen 1983).
[2]NA = Not available
[3]U = Unknown because no criterion level available
[4]ND = Not detected.

Table 1. Overview of the contaminant levels observed in edible flesh of brown shrimp and white shrimp.

Contaminant	Observed Range	Criterion[1]	Proportion Exceeding Criterion
Pesticides (ng/g wwt)			
DDD	0-49.4	5000	0%
DDE	0-8.9	5000	0%
DDT	0-6.5	5000	0%
Aldrin	0-2.8	300	0%
Chlordane	0-2.4	300	0%
Dieldrin	0-2.0	300	0%
Endosulfan	0-2.3	NA[2]	U[3]
Endrin	0-11.1	300	0%
Heptachlor	0-0	300	0%
Heptachlor Epoxide	0-1.7	300	0%
Hexachlorobenzene	0-6.1	200	0%
Lindane	0-0	200	0%
Mirex	0-10.5	100	0%
Toxaphene	0	5000	0%
Trans-Nonachlor	0-2.3	NA	U
PCBs (ng/g wwt)			
21 Congeners	0-91.3	500	0%
Total PCBs	0-95.3	2000	0%
Heavy Metals (µg/g wwt)			
Aluminum	0-36.1	NA	U
Arsenic	0-7.0	2	5%
Cadmium	0-0.18	0.5	0%
Chromium	0.02-1.1	1	1%
Copper	0-25.4	15	1%
Lead	0-1.6	0.5	2%
Mercury	0-0.7	1	0%
Nickel	0-1.0	NA	U%
Selenium	0-.12-1.4	1	2%
Silver	0-0.14	NA	U%
Tin	0-1.1	NA	U%
Zinc	1-14.6	60	0%

[1]Criteria were selected from FDA established limits for pesticides and PCBs (USFDA 1982, 1984) except hexachlorobenzene and lindane which are based on Swedish limits (Nauen 1983); no FDA limits exist for metals other than mercury; metals criteria reflect means of international limits (Nauen 1983).
[2]NA = Not available
[3]U = Unknown because no criterion level available

Table 2. Overview of the contaminant levels observed in edible flesh of Atlantic croaker.

Contaminant	Observed Range	Criterion[1]	Proportion Exceeding Criterion
Pesticides (ng/g wwt)			
DDD	0-18.5	5000	0%
DDE	0-104.8	5000	0%
DDT	0-20.7	5000	0%
Aldrin	0-22.5	300	0%
Chlordane	0-4.2	300	0%
Dieldrin	0-83.6	300	0%
Endosulfan	0-0	NA[2]	U[3]
Endrin	0-1.9	300	0%
Heptachlor	0-2.6	300	0%
Heptachlor Epoxide	0-1.6	300	0%
Hexachlorobenzene	0-6.3	200	0%
Lindane	0-2.0	200	0%
Mirex	0-2.4	100	0%
Toxaphene	0	5000	0%
Trans-Nonachlor	0-6.1	NA	U
PCBs (ng/g wwt)			
21 Congeners	0-20.6	500	0%
Total PCBs	0-56.7	2000	0%
Heavy Metals (µg/g wwt)			
Aluminum	0-88.6	NA	U
Arsenic	0-39.9	2	62%
Cadmium	0-0	0.5	0%
Chromium	0-1.04	1	1%
Copper	0-11.6	15	0%
Lead	0-6.5	0.5	5%
Mercury	0-1.6	1	1%
Nickel	0-30.5	NA	U
Selenium	0.1-0.6	1	0%
Silver	0-0.1	NA	U
Tin	0-0.1	NA	U
Zinc	4.8-28.4	60	0%

[1] Criteria were selected from FDA established limits for pesticides and PCBs (USFDA 1982, 1984) except hexachlorobenzene and lindane which are based on Swedish limits (Nauen 1983); no FDA limits exist for metals other than mercury; metals criteria reflect means of international limits (Nauen 1983).
[2] NA = Not available
[3] U = Unknown because no criterion level available

Table 3. Overview of the contaminant levels observed in edible flesh of catfish.

was low. However, a few contaminants (selected heavy metals) occurred in high enough concentrations to exceed international guidelines in small portions of the populations examined. These contaminants were arsenic, lead, mercury, chromium and copper. Concentrations of arsenic are a total of both organic and inorganic forms and may not be available to the organisms. Because of the paucity of information concerning U.S. standards for heavy metals other than mercury in fish, the criteria levels used for metals in Table 1 through 3 (i.e., World Health Organization guidelines) may not be acceptable. However, the contaminant data are available to be compared to any criteria and can be used to track potential trends in contaminant concentrations in flesh for the croaker, catfish, and shrimp populations in the Louisianian Province.

INTEGRATION OF ESTUARINE CONDITIONS

The overall condition of the estuaries in the Louisianian Province has been summarized by combining the benthic index, marine debris, water clarity and tissue contaminants, weighted equally. This single value includes an index of societal values (aesthetics) and estuarine biotic integrity based on benthic assemblages (Fig. 5). Indicators relating to biotic integrity and aesthetics were used to estimate overall environmental conditions in the estuaries. Forty-six percent of the estuarine area in the Louisianian Province showed evidence of degraded biological resources or was impaired with respect to its ability to support activities valued by society (Fig. 5). Of the 25,725 km^2 of estuarine surface area in the Louisianian Province, 11,834 km^2 were potentially degraded based on the 1993 sampling.

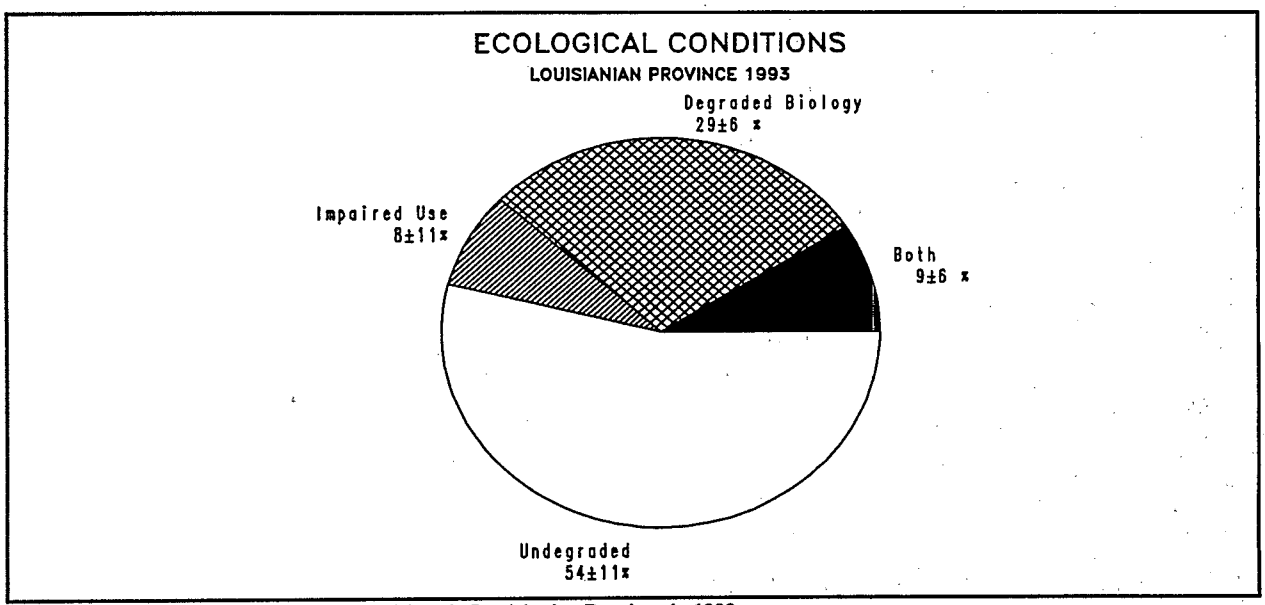


Figure 5. Summary of environmental conditions in Louisianian Province in 1993.

The locations of degraded biological resources were sometimes different from those having aesthetic problems. Both sets of conditions were found in 9±6% of the estuarine area, whereas degraded biological conditions alone were found in 29±6% of the province, and poor aesthetics were found in 8±11% (Fig. 5).

POLLUTANT EXPOSURE

While EMAP-E's major objective is to describe the status of estuaries using indicators of ecological condition, we have taken numerous measurements of the magnitude and extent of pollutant exposure in order to ascertain some preliminary links between observed estuarine degradation and observed pollutant exposure. Many of these pollutant measures are described in detail in Section 2; however, a few exposure indicators are discussed below: dissolved oxygen concentrations, sediment toxicity, and sediment contaminants.

Dissolved oxygen is a fundamental requirement for all estuarine organisms. A threshold concentration of 4 to 5 ppm is used by many states to set water quality standards. Bottom waters in 33%±11% of the Louisianian Province had point measurements of dissolved oxygen concentrations that failed to meet the 5ppm criterion (Fig. 6). A concentration of approximately 2 ppm is often used as a threshold for oxygen concentrations thought to be extremely stressful to most estuarine organisms. Results from the 1993 Louisianian Province Demonstration indicate that point measurements of bottom dissolved oxygen concentrations below this threshold were found in 7±6% of the province (Fig. 6).

Two types of dissolved oxygen measurements were taken in 1993: point measurements and continuous measurements. Continuous measurements were used to supplement point measures, as some estuaries appear to undergo severe dissolved oxygen stress during nighttime

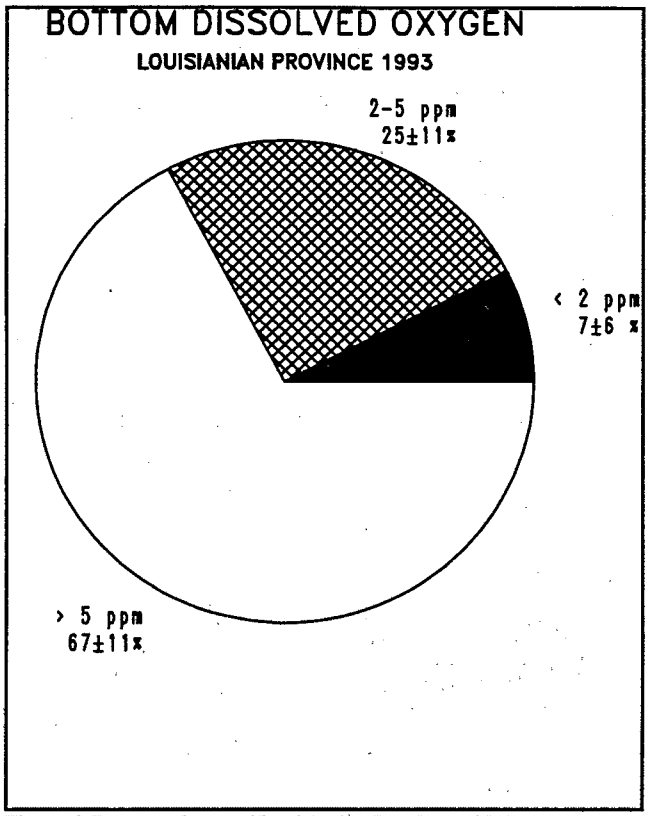


Figure 6. Percent of area of Louisianian Province with instantaneous dissolved oxygen concentrations in bottom waters < 2 ppm, 2-5 ppm, and > 5 ppm.

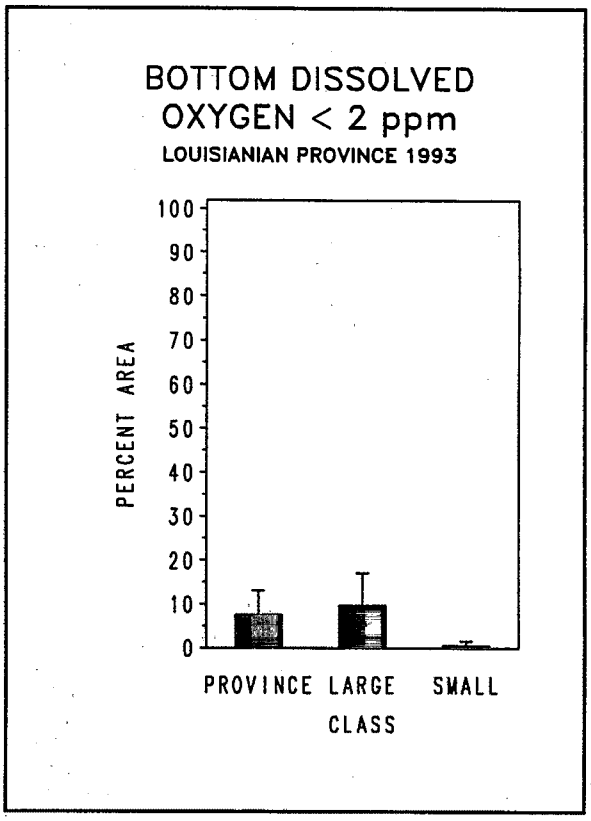


Figure 7. Percent of area having instantaneous dissolved oxygen concentrations in bottom waters of < 2 ppm for large estuaries (large), small estuaries (small), and the Louisianian Province, with 95% confidence interval.

hours. Point measurements taken during daylight hours could erroneously characterize a site as having acceptable dissolved oxygen concentrations when that site receives severe dissolved oxygen stress for several hours every night. Dissolved oygen concentrations <2.0 ppm were found in a higher percentage of estuaries (2.6%) based on the use of the continuous measurements versus the instantaneous measurements (Figs. 6-9).

Sediment bioassays are the most direct measure available for estimating the potential for contaminant-induced effects in biological communities. These tests provide information that is independent of chemical characterizations and ecological surveys (Chapman 1988). Direct measures of sediment contaminant concentrations do not show which concentrations may adversely affect biological resources because many chemicals are bound tightly to sediment particles or are chemically-complexed (USEPA 1989, Long and Morgan 1990). Sediment toxicity tests avoid this problem by indicating when contaminant concentrations have the potential to impact biological resources. Laboratory bioassays were conducted to determine if the sediments in the

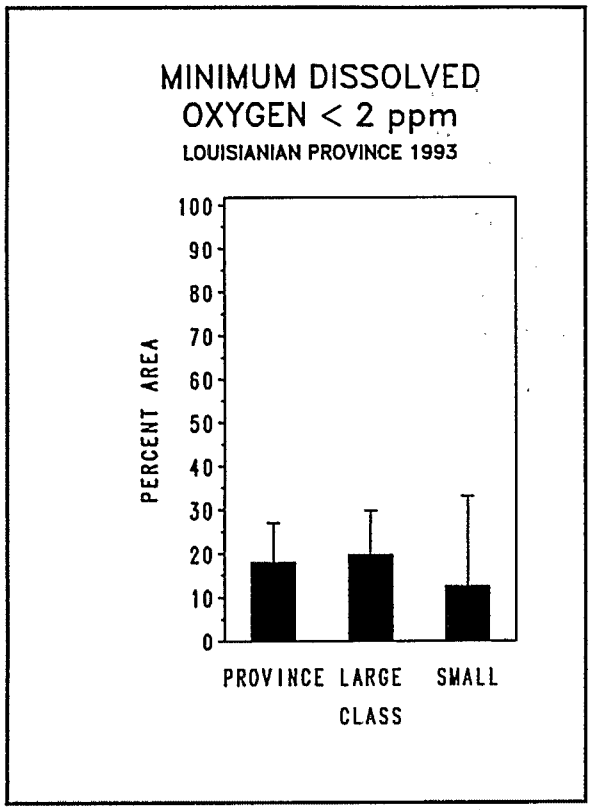


Figure 8. Percent of area having minimum dissolved oxygen concentrations in bottom waters of < 2 ppm for large estuaries (large), small estuaries (small), and the Louisianian Province, with 95% confidence interval.

Louisianian Province were toxic to representative estuarine organisms. Based upon the results of these tests, 1.4±2.5% of the Louisianian Province contained sediments that were toxic to estuarine organisms (Figure 10). Because *Ampelisca abdita*, the test organism used in the bioassays is not common to the Louisianian Province, additional testing was completed using a common mysid. The results of this mysid testing generally agree with those found using *Ampelisca* with 9.9±6.9% of the province showing toxicity. The proportion of area containing toxic sediments was very different between the two classes (Fig. 10), with the highest proportion occurring in the large estuaries (1.6±2.2%) and a smaller portion in the small estuaries (0.9±1.6%).

Measurements of concentrations of contaminants in sediments were used to estimate the areal extent of sediment having pollutant concentrations that are above hypothesized levels that could cause biotic effects and that could be attributed to human activities. For this summary, sediment contaminants will be discussed as five major groups: heavy metals, alkanes and isoprenoids, polynuclear aromatic hydrocarbons (PAHs), pesticides, and polycyclic chlorinated biphenyls (PCBs), and as a single group of contaminated substances. For all contaminants, the criteria used to assess potential for degradation were the Long and Morgan (1990) and Long *et al* (1995) median values (ER-M) associated with biological effects. All values above these median criteria were assessed as being representative of sediment degradation. In addition, the 10% Long and Morgan values (ER-L) were used to assess locations where some contamination occurred, but at levels that could result in ecological problems some of the time. These criteria levels are not available for all toxic substances. The criteria used for contaminants are shown in Table 4.

Natural sources of metals and chemical and physical processes in estuaries may concentrate metals in fine-grained sediments or in depositional areas of estuaries. In addition to the criteria-based assessments described above, analyses were conducted to distinguish areas with elevated concentrations of metals as a result of anthropogenic enrichment by adjusting for aluminum sediment concentrations. Based upon these two approaches, 20±7% of the Louisianian Province has sediments with

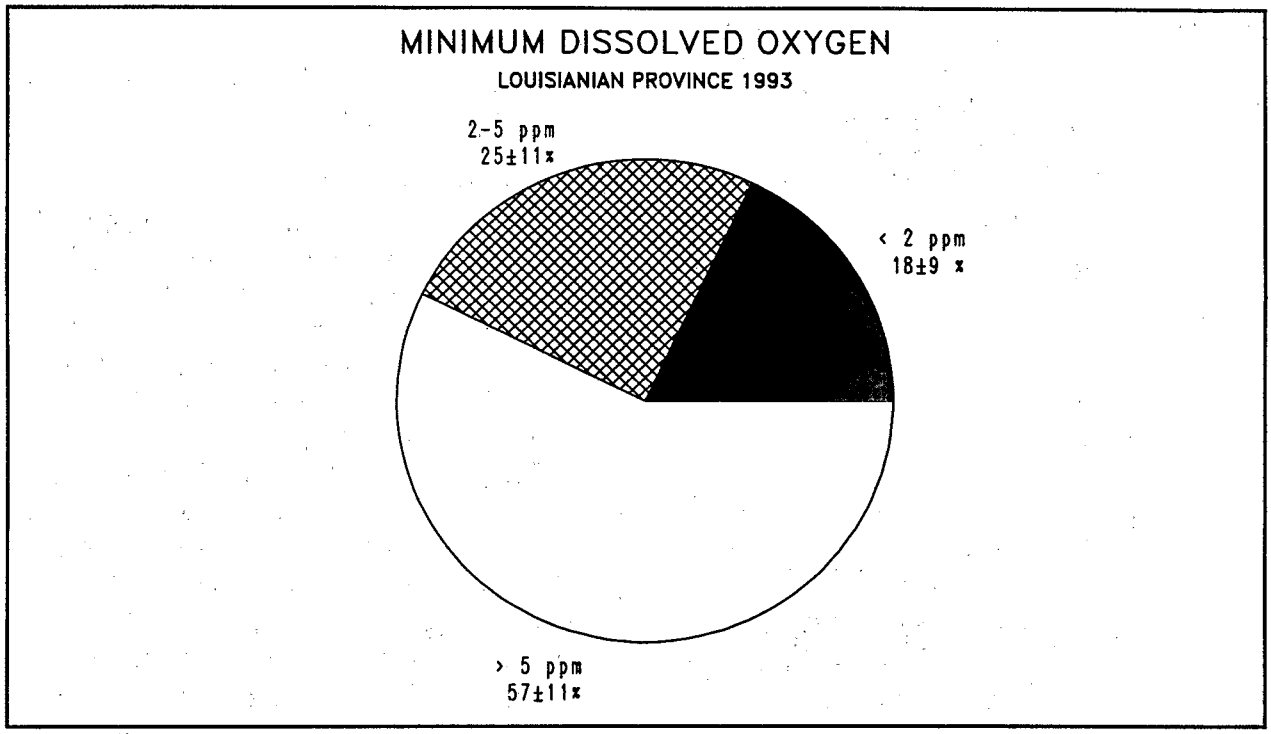


Figure 9. Percent of area of Louisianian Province with minimum dissolved oxygen concentrations in bottom waters < 2 ppm, 2-5 ppm, and > 5 ppm based on 24 hours of data.

elevated concentrations of one or more heavy metals based on the criteria values, and 16±7% of the area has heavy metal concentrations that were higher than would be expected based on aluminum background concentrations (Fig. 11).

Alkanes and isoprenoids are hydrocarbons associated with the petrochemical industry (drilling, transport, refinement). While 27 individual alkanes were examined, total alkanes were used to provide an overall assessment of sediment contamination due to alkanes. No biological effects guidelines exist for alkanes. However, a criteria value of >7000 ppb total alkanes was used to characterize a degraded estuarine condition. An intermediate criterion on 5000-7000 ppb total alkanes was used as indicative of potential contamination. None of the sediments in the province collected in 1993 are characterized by alkane concentrations in excess of 7000 ppb.

However, a criterion is available for total PAHs based on the Long *et al* (1995) estimate for sediment concentrations resulting in biological effects 50% of the time >44,792 ppb. Due to the magnitude of this concentration, we also examined the concentration range that produced ecological effects >10% of the time >4022 ppb total PAHs. No total PAH concentrations in the observed Louisianian Province sediments exceeded 44,792 ppb. Only 4±4% of the province is characterized by the intermediate total PAH concentration of > 4022 ppb. The intermediate level of PAHs was found primarily in large estuarine systems comprising 5±6% of

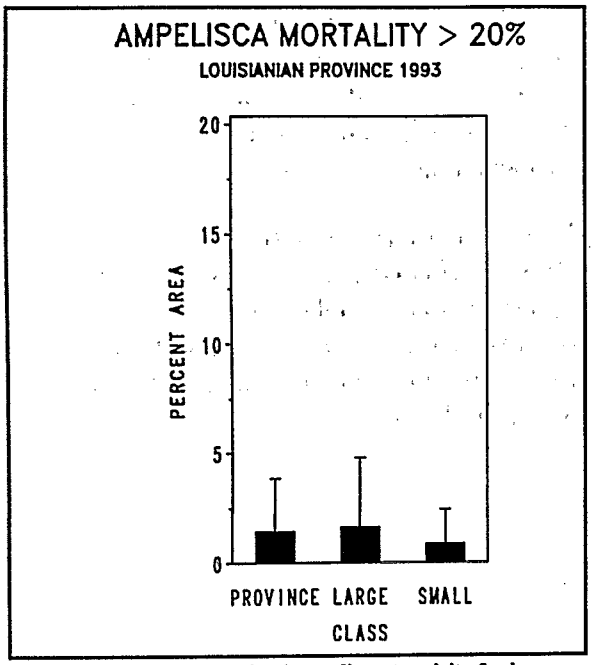


Figure 10. Percent of area having sediment toxicity for large estuaries (large), small estuaries (small), and the Louisianian Province, with 95% confidence interval.

those sediments.

Polycyclic chlorinated biphenyls (PCBs) represent a very toxic compound in the environment. Twenty individual PCB congeners were examined in the 1993 Louisianian Province Demonstration. Long *et al* 1995 provide a criterion of >180 ppb total PCBs as the concentration likely to result in ecological effects. They provide a secondary concentration of >22.7 ppb at which some effects might be expected. Total PCB concentrations in observed Louisianian Province sediments did not exceed 400 ppb. Less than 1% of the Louisianian Province sediments were characterized by total PCB concentrations > 22.7 ppb.

Pesticides are introduced into the estuarine environment through three pathways: direct

Contaminant	ER-L	ER-M
Inorganic (ppm)		
Antimony	Z	25
Arsenic	8.2	70
Cadmium	1.2	9.6
Chromium	81	370
Copper	34	270
Lead	46.7	218
Mercury	0.15	0.71
Nickel	20.9	51.6
Silver	1.0	3.7
Zinc	150	410
Organic (ppb)		
Acenaphthene	16	500
Acenaphthylene	44	640
Anthracene	85.3	1100
Fluorene	19	540
2-methylnaphthalene	70	670
Naphthalene	160	2100
Phenanthrene	240	1500
Benzo(a)anthracene	261	1600
Chrysene	384	2800
Dibenzo(a,h)anthracene	63.4	260
Fluoranthene	600	5100
Pyrene	665	2600
Total PAH	4022	44792
Total LMW PAH	552	3160
Total HMW PAH	1700	9600
p,p-DDE	2.2	27
Total DDT	1.6	46.1
Total PCBs	22.7	180
DDD	2.0	20
DDE	2.0	15
DDT	1.0	7
Chlordane	0.5	6
Dieldrin	0.02	8
Endrin	0.02	45

Table 4. Guidelines used to determine sediment contamination where ER-L indicates the concentration at which 10% of bioassays showed adverse biological effects and ER-M indicates the concentration at which 50% of bioassays showed adverse biological effects (Long and Morgan, 1990; Long *et al* 1995).

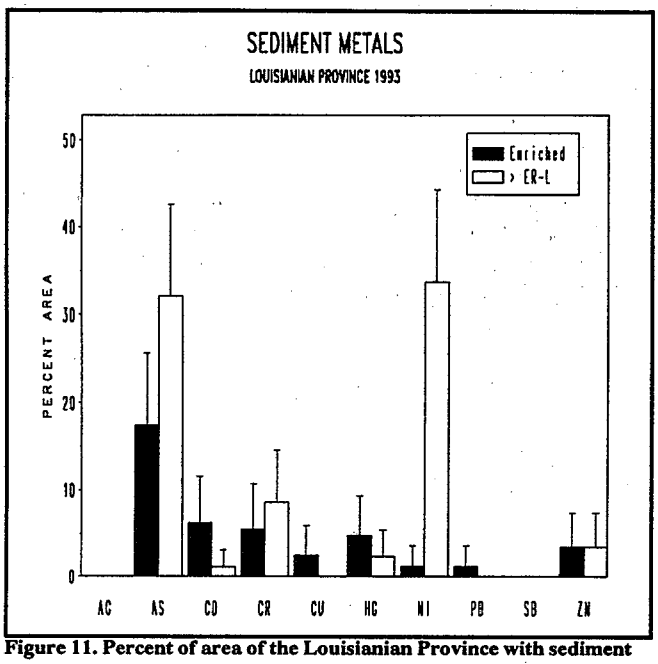


Figure 11. Percent of area of the Louisianian Province with sediment metal concentrations > 10% Long-Morgan criteria or greater than expected based on aluminum concentrations.

emission as a result of point source discharge (generally through manufacture or disposal), non-point emission through agricultural or horticultural application, and atmospheric through deposition of volatilized materials. In the 1993 Louisianian Province Demonstration, 25 pesticides and derivatives were examined. For this summary, total pesticides, total DDT, and total chlordane are reported. Generally accepted sediment quality criteria are not yet available and even reasonable criteria are available for only 9 of the 25 pesticides examined. Long and Morgan (1990) report the following critical concentrations for DDT, DDD, DDE, chlordane, dieldrin, and endrin: 7 ppb, 20 ppb, 15 ppb, 6 ppb, 8 ppb, and 45 ppb, respectively.

Neither DDT criteria value of 7 ppb or the chlordane criteria value of 6 ppb were exceeded for the sediments in the Louisianian Province.

Endrin or Dieldrin concentrations did not exceed the median criterion. However, 18% of the sediment contained endrin at > 0.02 ppb and 57% of the sediments had dieldrin concentrations > 0.02 ppb.

Ninety-five percent confidence intervals (95% CI) were calculated for all parameters described in this summary. Table 5 provides the 95% confidence intervals for the major indicators for the proportion of the province and the three estuarine classes.

Parameter	Province	Large Estuary	Small Estuary
N	93	62	31
ABIOTIC CONDITION			
Marine Debris	11(7)	10(7)	14(18)
Water Clarity			
PAR < 10%	18(8)	16(9)	22(18)
PAR < 25%	45(12)	44(18)	45(27)
Silt-Clay Content			
< 20%	21(9)	19(10)	26(19)
> 80%	35(11)	34(12)	38(25)
Alkanes			
Total > 7000 ppb	9(6)	7(7)	13(13)
PAHs			
Total > 4000 ppb	4(4)	5(6)	< 1(1)
PCBs			
Total > 22.7 ppb	<1[1]	0(0)	<1[1]
Pesticides			
Chlordane > .5 ppb	8(6)	5(6)	12(17)
Dieldrin > .02 ppb	34(11)	31(12)	39(27)
Endrin > .02 ppb	4(4)	5(6)	1(2)
DDT > 1 ppb	< 1(1)	0(0)	< 1(1)
DDE > 2 ppb	2(3)	2(3)	1(2)
DDD > 2 ppb	< 1(1)	0(0)	< 1(1)
Metals			
Ag > 1 ppm	0(0)	0(0)	0(0)
As > 33 ppm	0(0)	0(0)	0(0)
Cd > 5 ppm	0(0)	0(0)	0(0)
Cr > 80 ppm	4(4)	5(6)	0(0)
Cu > 70 ppm	0(0)	0(0)	0(0)
Hg > .15 ppm	1(2)	2(3)	< 1(1)
Ni > 30 ppm	10(7)	12(8)	6(9)
Pb > 35 ppm	3(3)	3(5)	< 1(1)
Sb > 2 ppm	1(2)	2(3)	0(0)
Sn > 3 ppm	10(7)	10(8)	12(17)
Zn > 120 ppm	11(7)	12(8)	7(10)
Tributyltin			
TBT>0 ppb	71(10)	72(12)	67(23)
TBT>5 ppb	3(3)	3(5)	2(3)

Table 5. Estimates of the proportion of the Louisianian Province and estuarine classes experiencing the levels of the listed parameters and their associated 95% confidence interval in parentheses (N=number of sampling sites).

Parameter	Province	Large Estuary	Small Estuary
N	93	62	31
BIOTIC CONDITION			
Benthic Index	37(11)	34(12)	48(26)
Abundance < 10	5(5)	6(6)	2(3)
# Species < 2	< 1(0)	0(0)	1(1)
# Species≤5	14(7)	18(10)	5(4)
Fish Contaminants[1]			
Shrimp			
All > FDA Limits	13(0)	0(0)	33(0)
Croaker			
All > FDA Limits	0(0)	0(0)	0(0)
Marine Catfish			
Hg > FDA Limits	2(1)	0(0)	2(0)
Others > FDA Limits	0(0)	0(0)	0(0)
Bottom DO[2] < 2 ppm	7(6)	10(7)	1(1)
Bottom DO[2] ≤5 ppm	32(11)	34(12)	30(25)
Minimum DO < 2 ppm	18(9)	20(10)	12(21)
Sediment Toxicity	1(2)	2(3)	1(2)

[1] Percentage based on sample size rather than estuarine area
[2] Instantaneous dissolved oxygen measurements

Table 5 (*cont.*)Estimates of the proportion of the Louisianian Province and estuarine classes experiencing the levels of the listed parameters and their associated 95% confidence interval in parentheses (N=number of sampling sites).

SECTION 1

INTRODUCTION

The Environmental Monitoring and Assessment Program (EMAP) is a national program initiated by EPA's Office of Research and Development (ORD) (USEPA, 1992). EMAP is an integrated federal program; ORD is coordinating the planning and implementation of EMAP with other federal agencies including the Agricultural Research Service (ARS), Bureau of Land Management (BLM), U.S. Fish and Wildlife Service (FWS), National Biological Service (NBS), Forest Service (FS), U.S. Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA). These other agencies and offices participate in the collection and analysis of EMAP data and will use it to guide their policy decisions, as appropriate.

EMAP-Estuaries (EMAP-E) represents one portion of EMAP's efforts in near coastal environments and is jointly conducted by EPA/ ORD and NOAA. These efforts are designed to provide a quantitative assessment of the regional extent of coastal environmental problems by measuring status and change in selected ecological condition indicators. In 1993, EMAP-E continued a demonstration project in the estuaries of the Louisianian Province (i.e., all estuarine areas located along the coastline of the Gulf of Mexico between the Rio Grande River, TX, and Anclote Anchorage, FL). This Statistical Summary reports on the 1993 sampling effort.

1.1 OBJECTIVES OF THE 1993 LOUISIANIAN PROVINCE ESTUARINE SAMPLING

The specifics of the planning activities of the Louisianian Province Demonstration are documented in Summers *et al.* (1991). This continuing demonstration was held in the Louisianian Province to show the utility of regional monitoring programs for assessing the condition of estuarine resources. Sampling was conducted from July through August spanning 154 sites utilizing 30 field personnel and three program/logistical coordinators.

The objectives of the 1993 Louisianian Province Continuing Demonstration were to:

1) assess the condition of estuarine resources in the Louisianian Province using a probability-based sampling design; and,

2) develop and refine analytical procedures for using regional-scale monitoring data to assess the ecological status of estuaries and apply these procedures to establish the

baseline conditions in the Louisianian Province.

1.2 ENVIRONMENTAL VALUES AND ASSESSMENT QUESTIONS

The environmental value depicted by the EMAP-E in the Louisianian Province, as well as other provinces, is estuarine condition. The subvalues comprising condition are ecological integrity and societal values.

Ecological integrity is comprised of ecosystem quality (estuarine trophic state and acreage of unique habitats) and biotic integrity (benthic index and fish index). The primary assessment questions relating to ecological integrity addressed by the demonstration in the Louisianian Province are:

- What proportion of the bottom waters of the estuaries in the Louisianian Province experience hypoxia (i.e., dissolved oxygen concentrations < 2 ppm greater than 20% of the time)?
- What proportion of the estuarine sediments of the Louisianian Province has benthic community structure indicative of polluted environments?
- What proportion of the estuarine waters of the Louisianian Province is eutrophic?
- What proportion of fish populations in the Louisianian Province has characteristics similar to those indicative of polluted environments?

Societal values are characterized by consumptive uses (i.e., quantity and quality of fishery stocks) and non-consumptive uses (i.e., aesthetics and water contact). The primary assessment questions related to societal values are:

- What proportion of target fish in the Louisianian Province has contaminant concentrations in edible tissue greater than FDA action limits?
- What proportion of target fish in the Louisianian Province has external gross pathologies in excess of 0.5%?
- What proportion of the estuarine sediments in the Louisianian Province contains anthropogenic marine debris?
- What proportion of estuarine waters in the Louisianian Province has insufficient water clarity to permit < 10% of incident sunlight to reach a depth of 30 cm?
- What proportion of the estuarine waters in the Louisianian Province has unacceptable levels of pathogenic microbial agents?

In addition, several assessment questions relate to the relationships among the response indicators measured to address the above assessment questions and stressor conditions in the estuaries of the Louisianian Province. These questions are:

- Are observed areas of eutrophic condition in the Louisianian Province associated with stressor conditions?
- Are observed areas of poor biotic community conditions in the Louisianian Province associated with stressor conditions?
- Are observed areas of poor societal value conditions in the Louisianian Province

associated with stressor conditions?

Many of these assessment questions are addressed in this statistical summary; however, some of the associational questions are not addressed in this summary but are addressed in the Louisianian Province Demonstration Report (Summers *et al.* 1993a).

1.3 PURPOSE AND ORGANIZATION OF THIS REPORT

The purpose of this report is to provide estimates of the ecological condition of the estuarine resources of the Louisianian Province during 1993. This report is meant to be a summarization of all the data collected in the 1993 Demonstration. As a result, different topics are dealt with using varying levels of detail based on their importance to the estimation of ecological condition of the estuarine resources of the Louisianian Province.

The Statistical Summaries that will be produced by EMAP-E are meant to provide large quantities of information without extensive interpretation of these data. Interpretive reports are anticipated every 4 to 5 years or in specialized documents such as the Demonstration Report for the Louisianian Province (Summers *et al.* 1993a). As a result, the Statistical Summaries will not provide information concerning sampling methodologies, field logistics, the development of indicators, and design modifications. Additional or expanded sections on methods, logistics, designs, and indicators were included in the 1991 EMAP-E Statistical Summary (Summers et. al. 1993b). Also, to demonstrate the flexibility of the EMAP-E sampling design in the Louisianian Province, additional data presentations (i.e., across states and EPA regions) are provided which may not be presented in other future EMAP-E Statistical Summaries.

Section 2 provides information about the results of the 1993 Demonstration with details of the regional ecological "report card" for the estuaries of the Gulf of Mexico.

Section 3 summarizes the conclusions that can be drawn from the 1993 Demonstration in the Louisianian Province as they relate to the stated objectives.

Section 4 lists the literature cited in this report.

Appendix A provides a series of subpopulation estimates created from the base monitoring data to represent the conditions in the estuarine resources in the five Gulf states and in the portions of EPA Regions IV and VI located in the Louisianian Province.

SECTION 2

STATISTICAL SUMMARY

The following discussion is organized by indicator type into biotic and abiotic condition indicators and habitat indicators. In each instance, an indicator will be described minimally with text; the cumulative distribution function (CDF) for that indicator will delineate the frequency of occurrence of observations within the province, and pie charts and bar graphs will delineate the proportions of the province or estuarine class showing particular magnitudes.

2.1 BIOTIC INDICATORS

Biotic condition indicators are characteristics of the environment that provide quantitative evidence of the status of ecological resources and biological integrity of a sample site from which they are drawn (Messer 1990). Ecosystems with a high degree of biotic integrity (i.e., healthy ecosystems) are composed of balanced populations of indigenous benthic and water column organisms with species compositions, diversity, and functional organization comparable to natural habitats (Karr and Dudley 1981). Response measures include measurements of the kinds and abundances of biota present and human use parameters that describe human perceptions of the condition of estuarine systems. Biotic condition indicators in the 1993 Louisianian Province Demonstration included both measured and derived indicators: number of benthic species, abundance of total benthos, benthic community composition, benthic abundance by taxonomic group, a benthic index of condition based on bioindicators, number of fish species, abundance of finfish, fish community composition, target species abundances, fish lengths, a fish index of condition, and contaminants in fish and shellfish (i.e., pesticides, PCBs, and heavy metals).

2.1.1 NUMBER OF BENTHIC SPECIES

Total number of benthic species has been used to characterize the environment of estuarine habitats. Three replicate benthic grabs at each sampling location in the Louisianian Province resulted in a distribution of mean number of benthic species at a site ranging from 0 to nearly 90 species (Fig. 2-1). There are no significant differences in the cumulative distribution function of species richness based on 1 vs. 2 vs. 3 replicates, suggesting that, at least for region-wide characterizations of species distribution, a single replicate is acceptable. Selecting 2 and 5 species as critical values for "healthy" benthic communities based on comparisons of impacted and reference sites of similar salinity (Summers *et al* 1993b) results in none of the sediments in the province having near mono-specific stands of benthos, while 14±7% of the sediments have communities comprised of 5 or fewer species (Fig. 2-2). These areas with reduced numbers of benthic species are primarily located in the small estuary

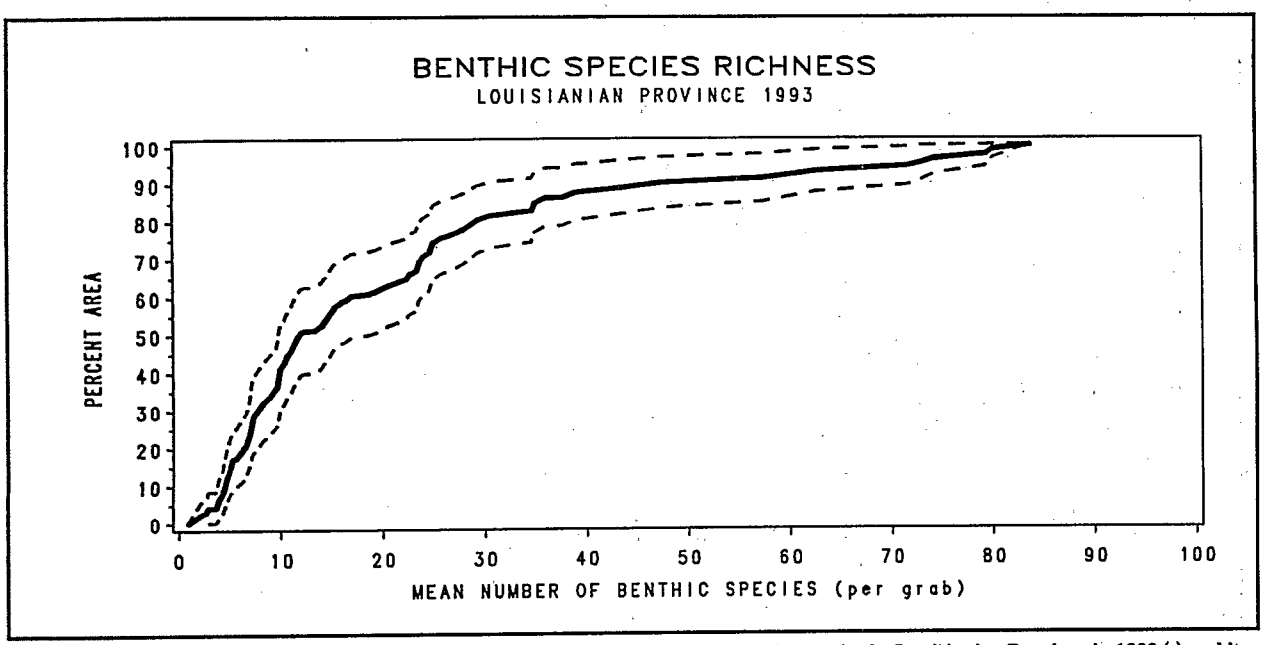


Figure 2-1. Cumulative distribution of mean benthic species richness in estuarine sediments in the Louisianian Province in 1993 (-) and its associated 95% confidence interval(--).

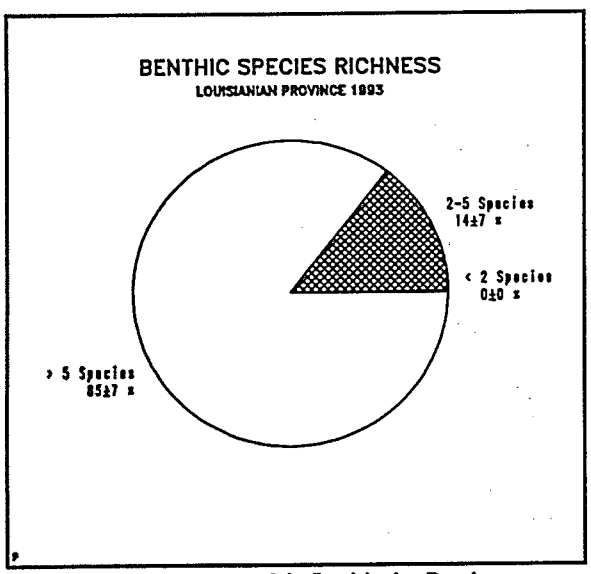


Figure 2-2. Percent of area of the Louisianian Province estuarine sediment associated with mean number of benthic species categories in 1993.

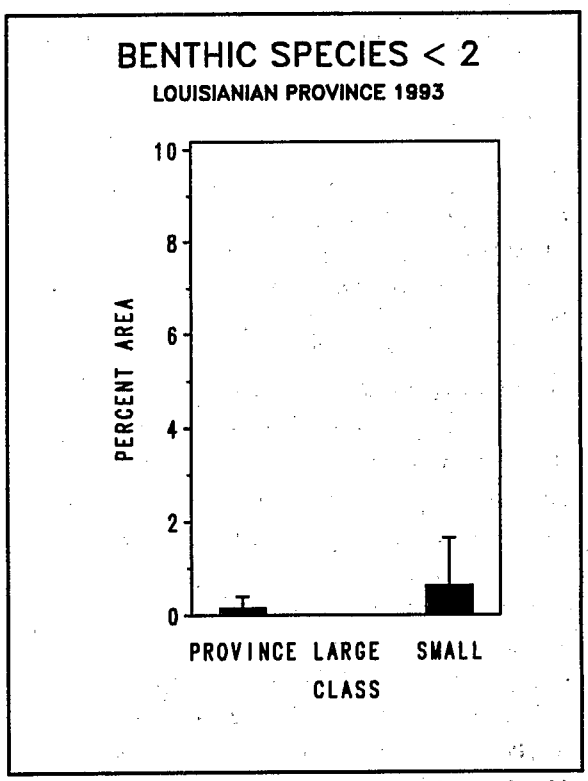


Figure 2-3 Percent of area having sediments with mean benthic species < 2 for large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

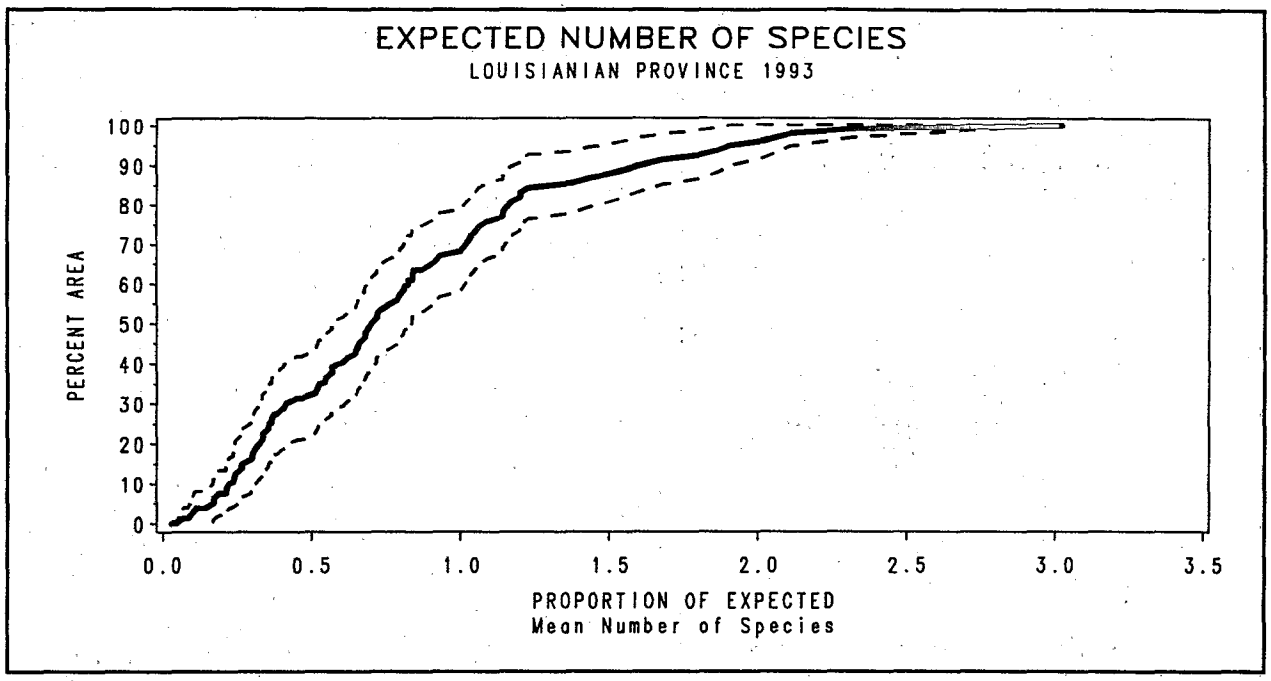


Figure 2-4. Cumulative distribution of proportion of expected number of benthic species observed in the estuarine sediments of the Louisianian Province in 1993 (-) and its associated 95% confidence interval (--).

classes (Fig. 2-3).

As a more meaningful comparison than simple total species numbers, the proportion of expected benthic species was estimated for the 1993 monitoring samples. This comparison was based on the 1991-1992 regression of salinity and mean number of benthic species per grab (Engle et al. 1994). This proportion of expected number of species, normalized for salinity differences, ranged from 0.0 to 3.1 (Fig. 2-4). About 20±9% of the sediments of the Gulf of Mexico estuaries had < 33% of the expected number of species based on salinity zone; 25±11% had between 33 to 66% of expected species; and, 55±11% had > 66% of the number of species expected based on salinity zone (Fig. 2-5). These areas of reduced expected numbers of benthic species are primarily located in the large estuaries (Fig. 2-6). Benthic diversity associated with the three grabs varies widely over the province (Fig. 2-7) with 3±4% of the province having a benthic Shannon-Weiner diversity index of less than 0.2 and 10±7% less than 0.4 (Fig. 2-8).

2.1.2 TOTAL BENTHIC ABUNDANCE

Benthic abundance is another indicator of the condition of biotic estuarine resources. Abundant benthic organisms, particularly in communities characterized by multiple species and feeding types, suggest a productive estuarine environment. Mean benthic abundance (Fig. 2-9) shows a range in benthic abundance in the Louisianian Province of 0 to about 2200 organisms per grab or over 44,000 organisms/ m^2. Using 10 organism/grab (about 200/m^2) and 25/grab (about 500/m^2) as indicators of low or marginal benthic abundance, respectively, 5±5% of Louisianian Province sediments have low

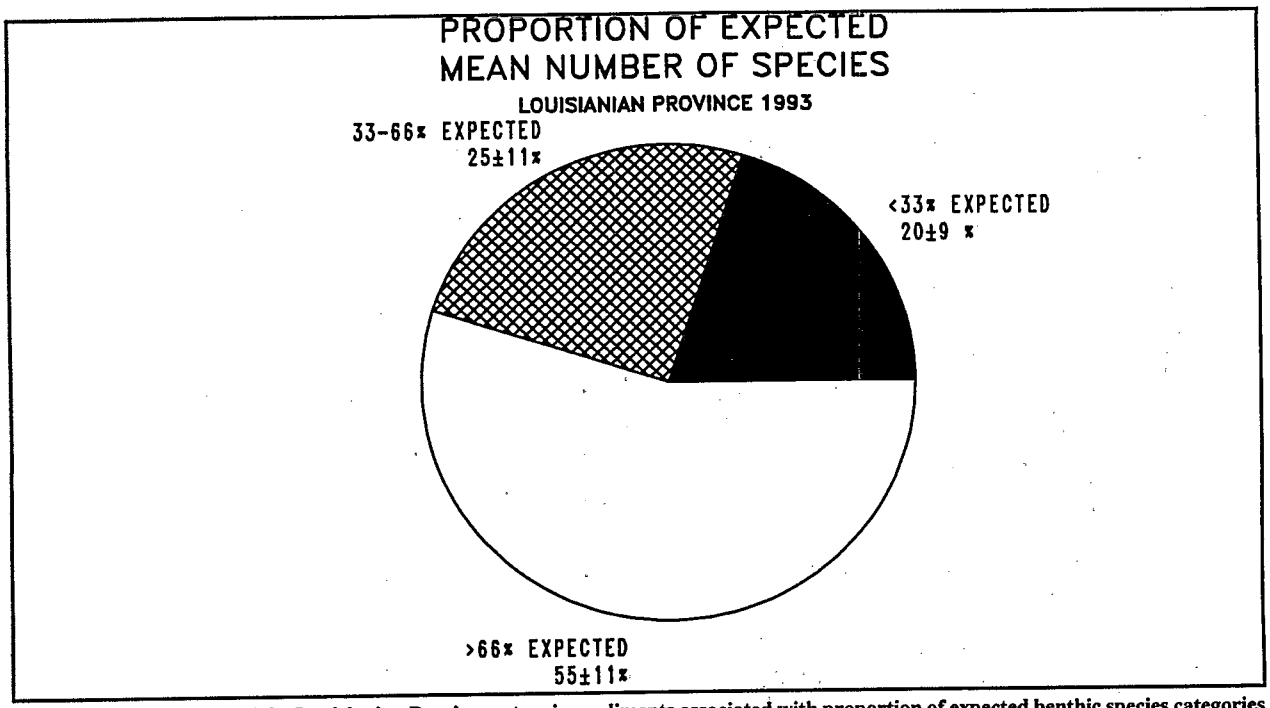


Figure 2-5. Percent area of the Louisianian Province estuarine sediments associated with proportion of expected benthic species categories in 1993.

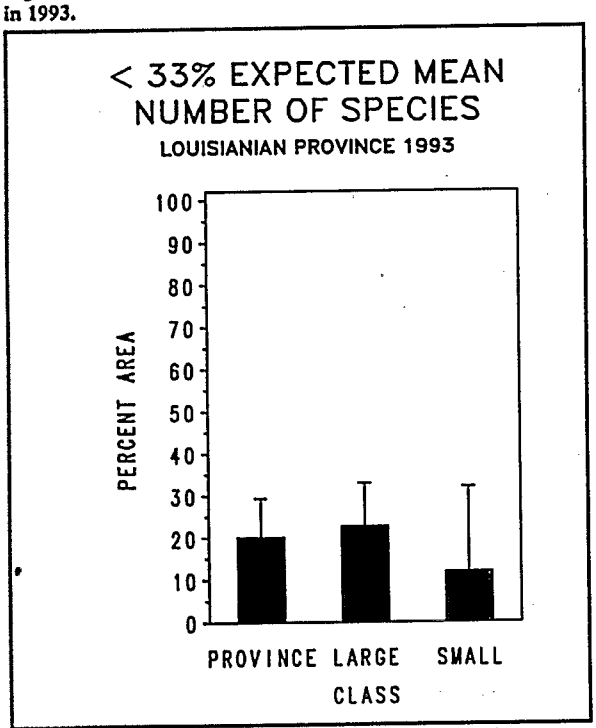


Figure 2-6. Percent area having sediments with proportion of expected benthic species < 33% in large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

benthic abundance and an additional 15±8% have marginal abundance (Fig. 2-10). These areas of low abundance are primarily associated with large estuaries (Fig. 2-11).

2.1.3 BENTHIC ABUNDANCE BY TAXONOMIC GROUP

The cumulative distribution functions can be used to describe the breakdown of the total benthic abundance described above into major taxonomic groups (Figs. 2-12, 2-13, 2-14, 2-15). Forty percent of the sediments sampled in the 1993 Louisianian Province Demonstration did not have amphipods as part of the community (Fig. 2-12), while 20% did not have gastropods (Fig. 2-13). Tubificids are absent from 60% of sediments while polychaetes were found in most of the sediments sampled (Figs. 2-14 and 2-15).

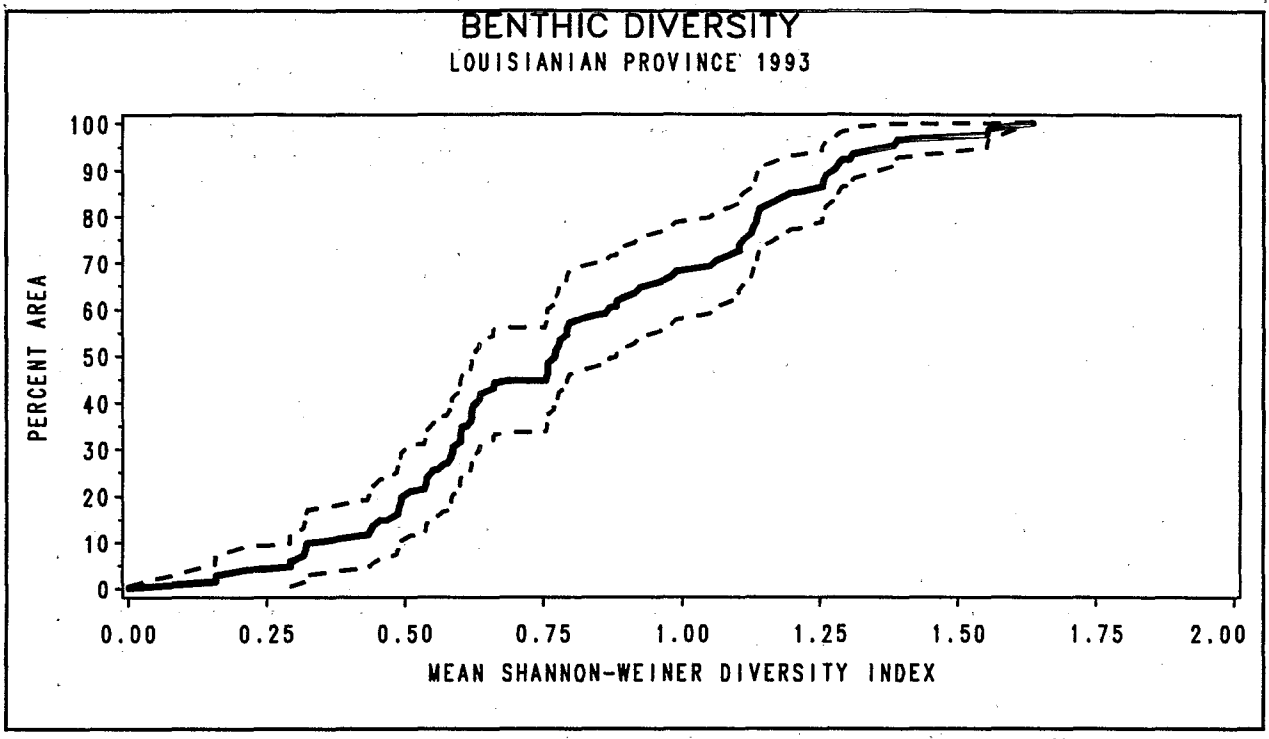


Figure 2-7. Cumulative distribution of benthic diversity in estuarine sediments in the Louisianian Province in 1993 (-) and its associated 95% confidence interval (--).

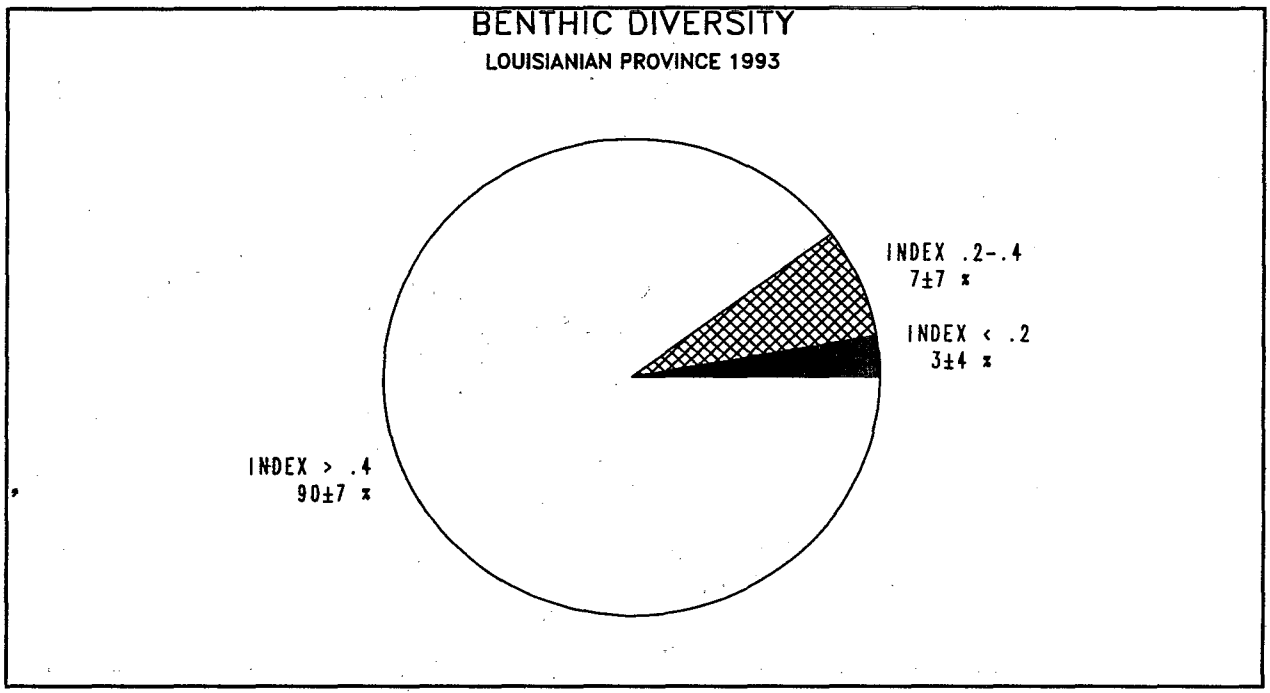


Figure 2-8. Percent area of the Louisianian Province estfiarine sediments associated with benthic diversity categories in 1993.

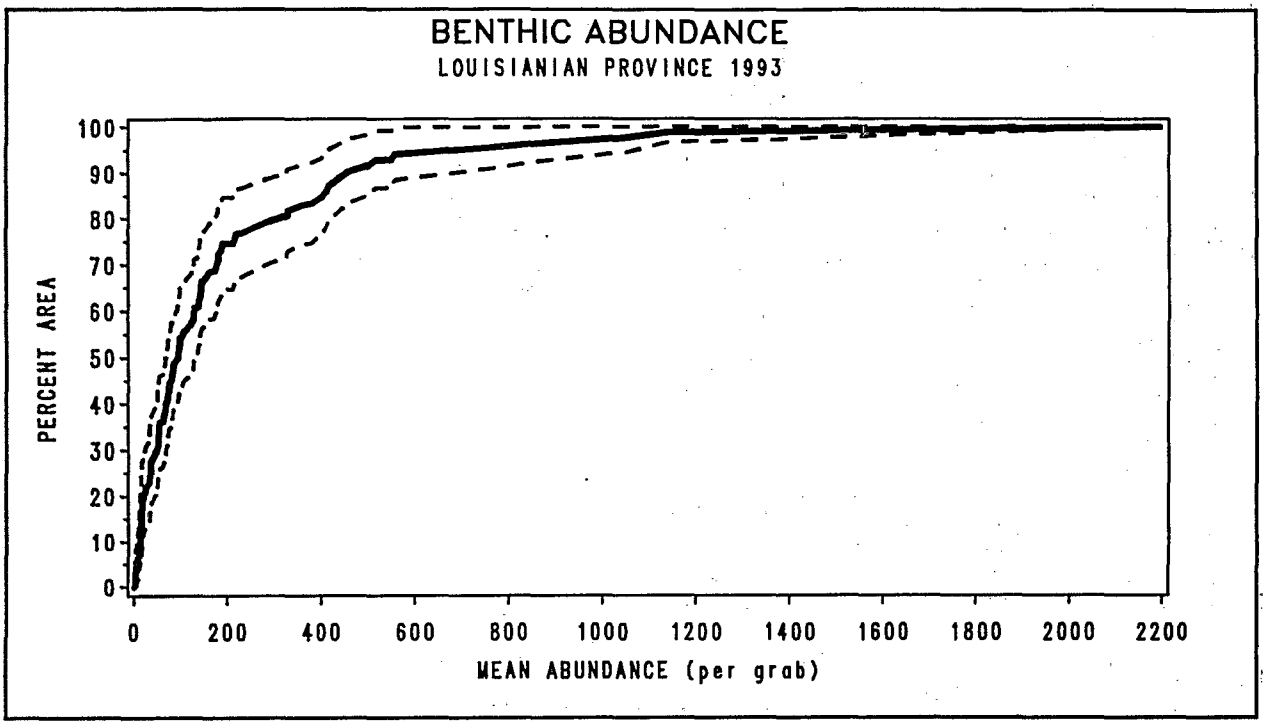


Figure 2-9. Cumulative distribution of mean abundance per grab in estuarine sediments in the Louisianian Province in 1993 (-) and its associated 95% confidence interval (--).

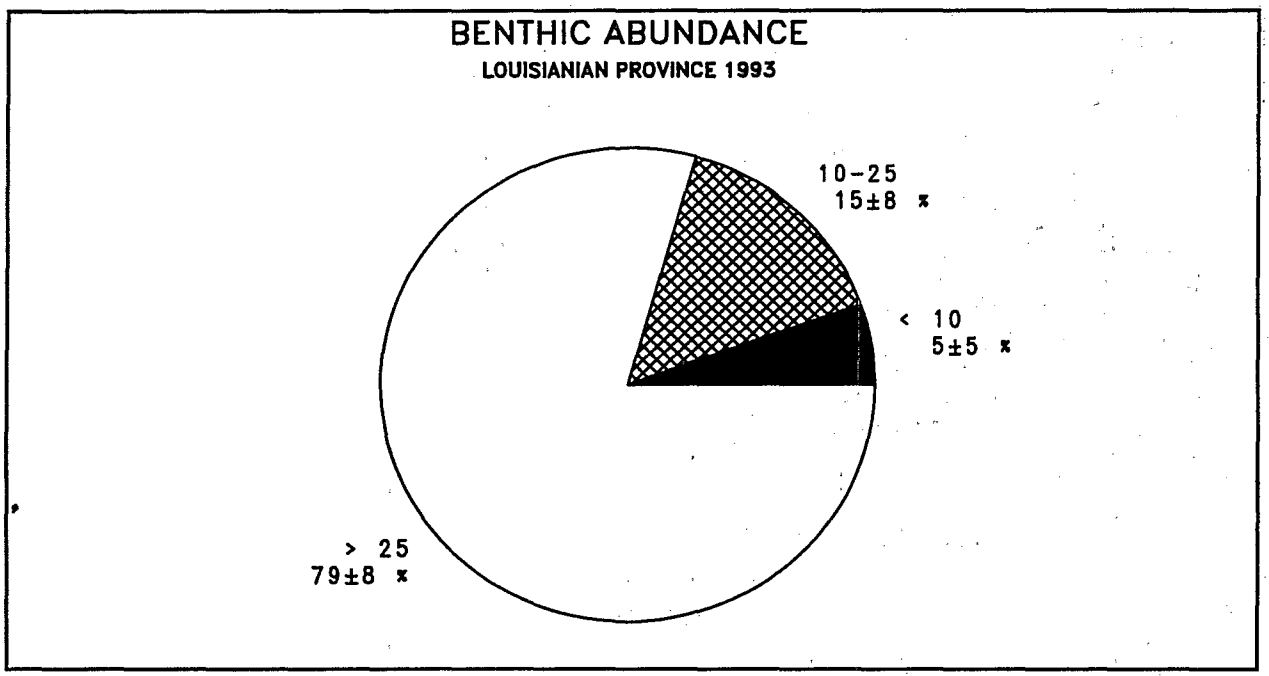


Figure 2-10. Precent area of the Louisianian Province estuarine sediments associated with benthic abundance categories in 1993.

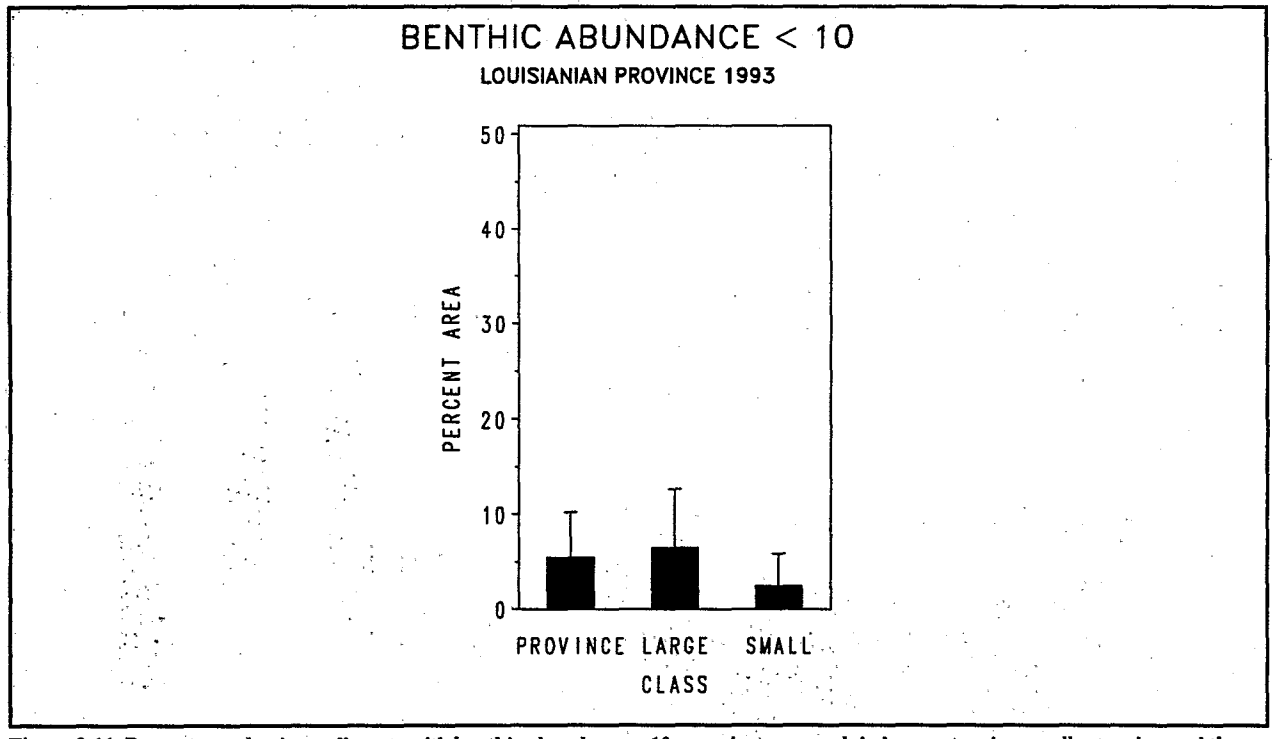


Figure 2-11. Percent area having sediments with benthic abundance < 10 organisms per grab in large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

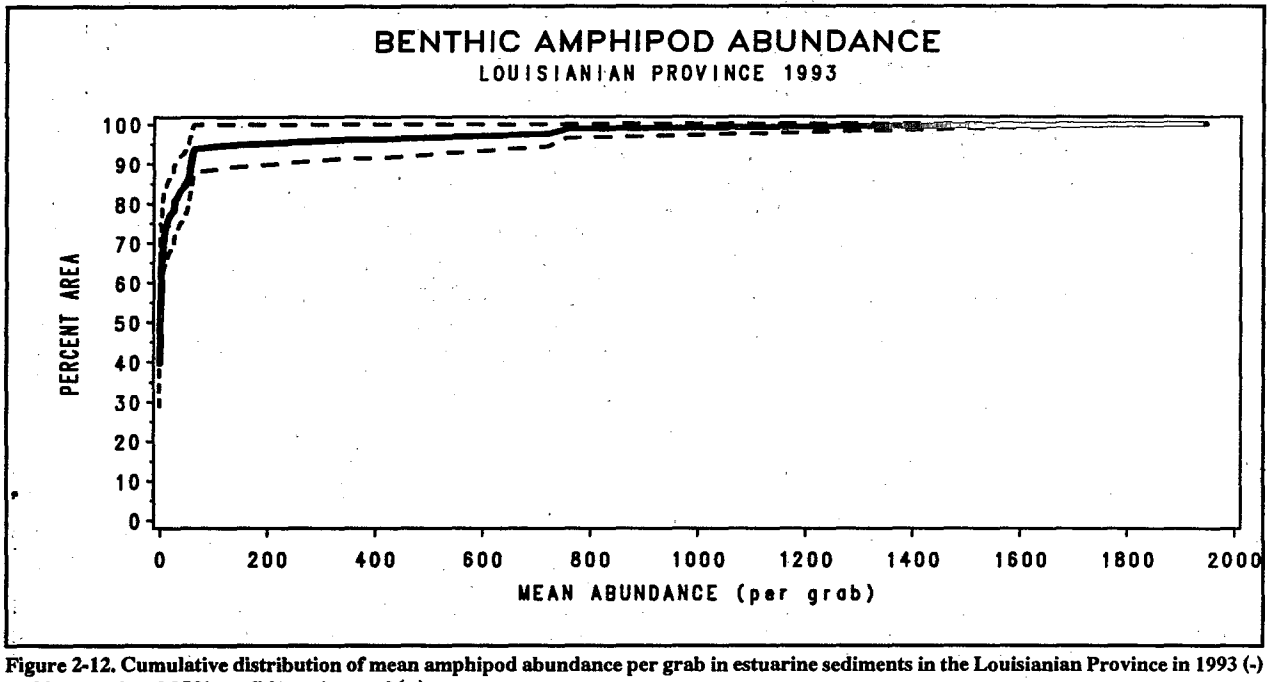


Figure 2-12. Cumulative distribution of mean amphipod abundance per grab in estuarine sediments in the Louisianian Province in 1993 (-) and its associated 95% confidence interval (--).

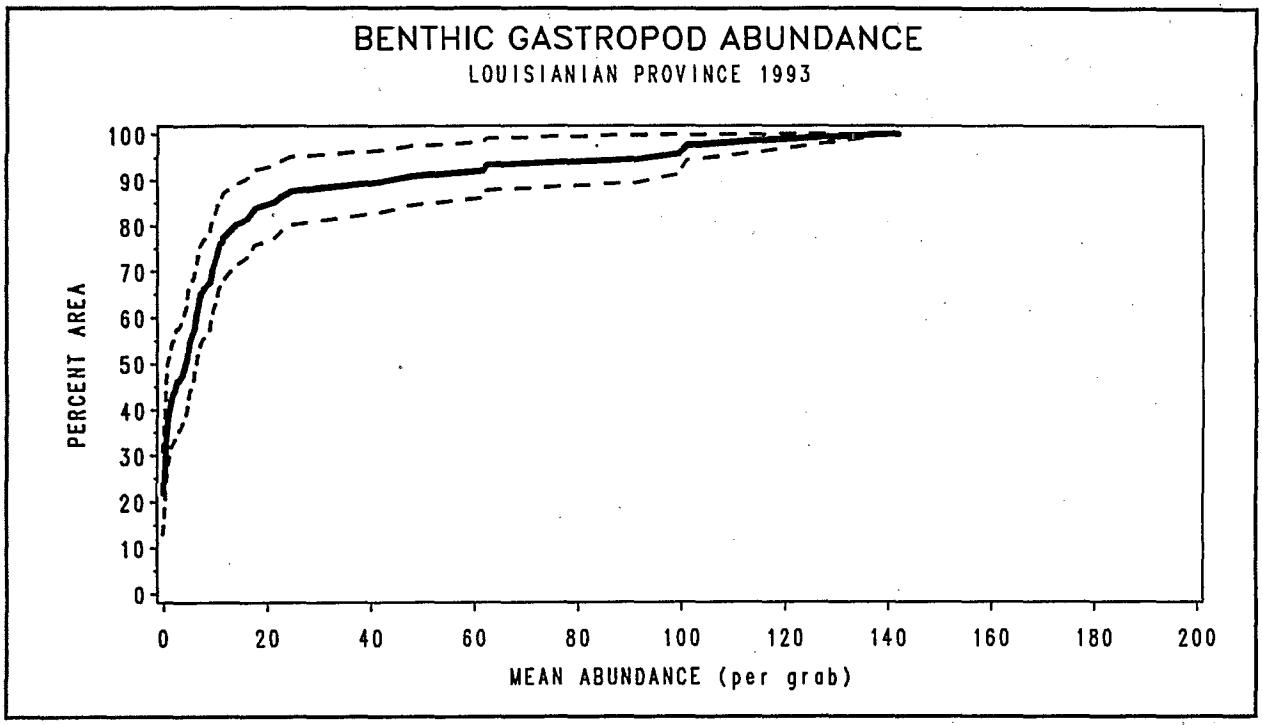


Figure 2-13. Cumulative distribution of mean gastropod abundance per grab in estuarine sediments in the Louisianian Province in 1993 (-) and its associated 95% confidence interval (--).

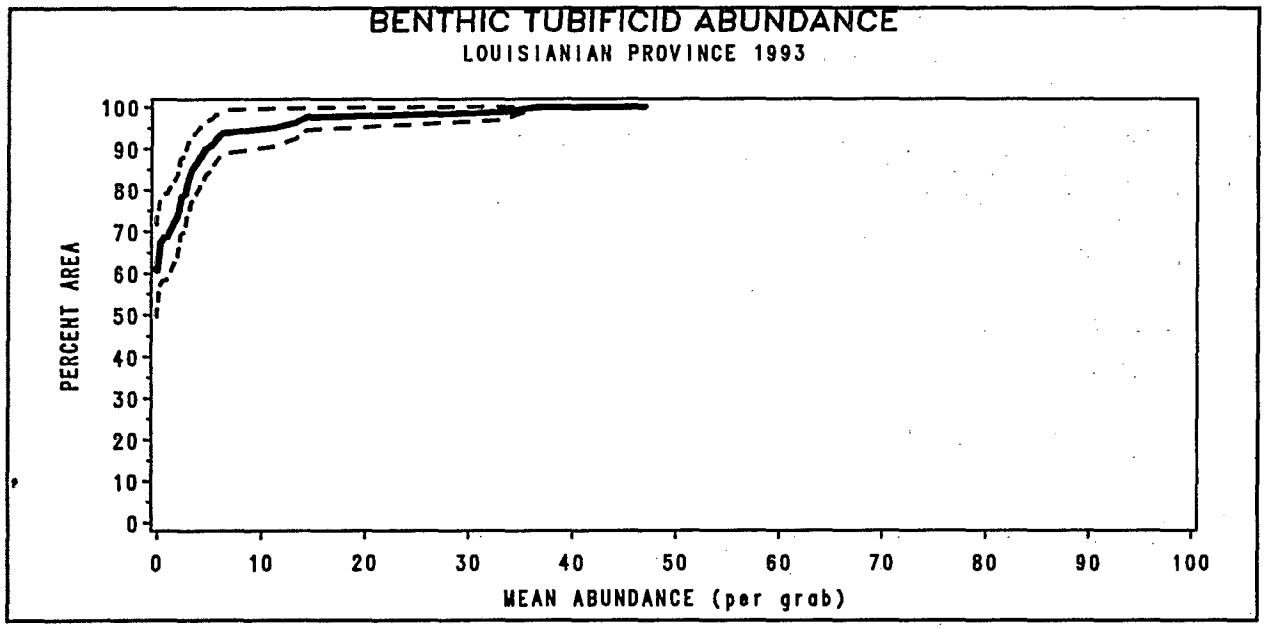


Figure 2-14. Cumulative distribution of mean tubificid oligochaete abundance per grab in estuarine sediments in the Louisianian Province in 1993 (-) and its associated 95% confidence interval (--).

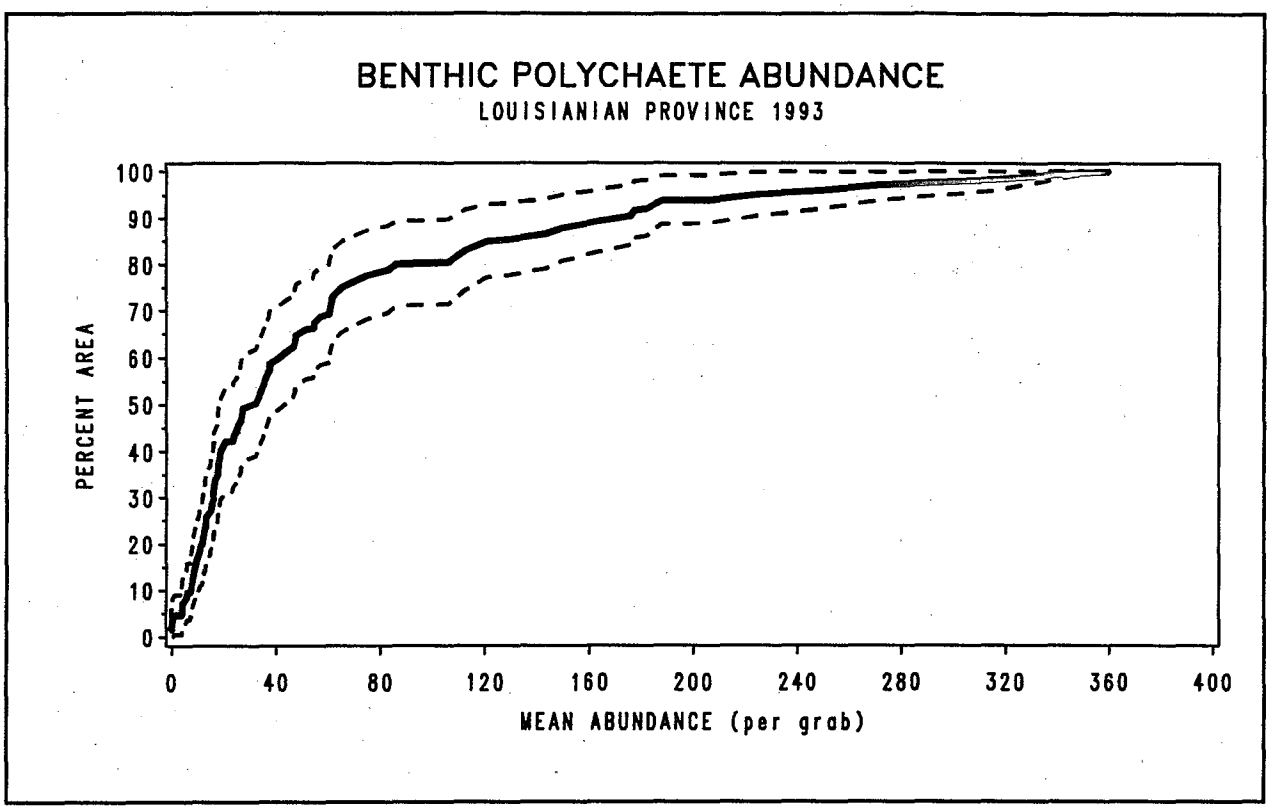


Figure 2-15. Cumulative distribution of mean polychaete abundance per grab in estuarine sediments in the Louisianian Province in 1993 (–) and its associated 95% confidence interval (--).

2.1.4 BENTHIC INDEX

About 37±11% of the sediments in the Louisianian Province contained stressed or degraded benthic communities as indicated by benthic index < 4.0 (Fig. 2-16). The highest proportion of the communities occurred in small estuaries (48±26%) (Fig. 2-17). These figures do not suggest that these stressed communities are solely the result of anthropogenic influences. Some of the poor benthic communities described could be the result of natural conditions (e.g., naturally induced hypoxia). However, 40% of the differences observed between stressed and unstressed benthic communities were associated with elevated concentrations of sediment contaminants (namely, copper, silver, mercury, and PAHs) and sediment toxicity, while none of the differences were attributable to low dissolved oxygen concentrations. The associations for the remaining 60% of the differences were either unknown or related to habitat variations (e.g., sediment enrichment).

2.1.5 NUMBER OF FISH SPECIES

Total number of fish species has been used to characterize the environmental condition of estuarine habitats. Dual 10-min trawls, taken at each sampling location in the Louisianian Province, resulted in a distribution of total number of nekton species per trawl ranging from 0 to 9 species (Fig. 2-18), with a total of 88

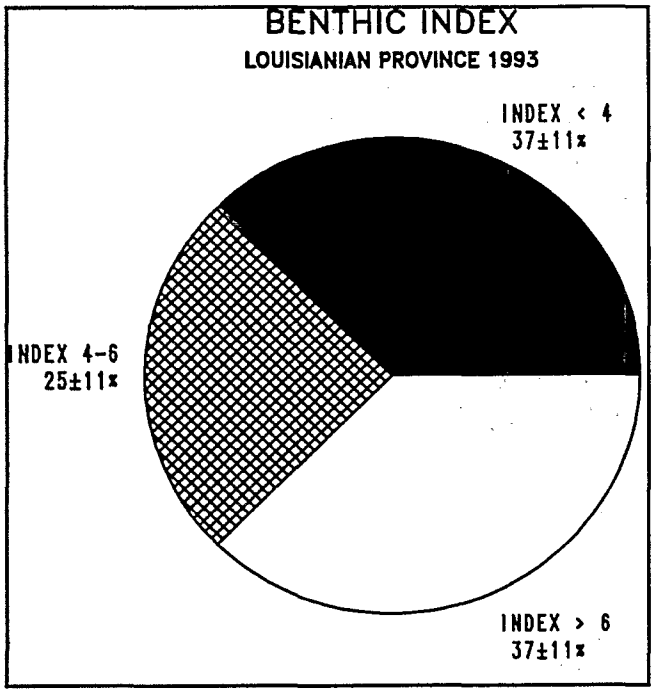


Figure 2-16. Percent of area of the Louisianian Province estuarine sediments associated with 1991-1992 revised benthic index categories in 1993.

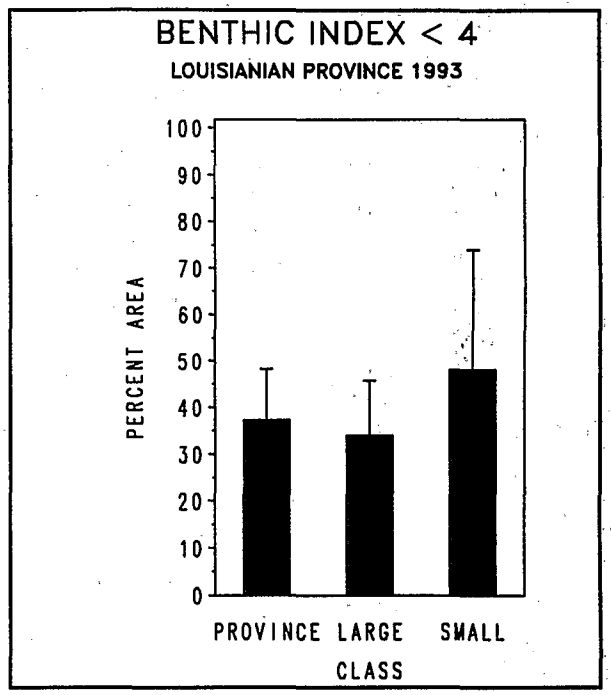


Figure 2-17. Percent of area having sediments with benthic index <4.0 in large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

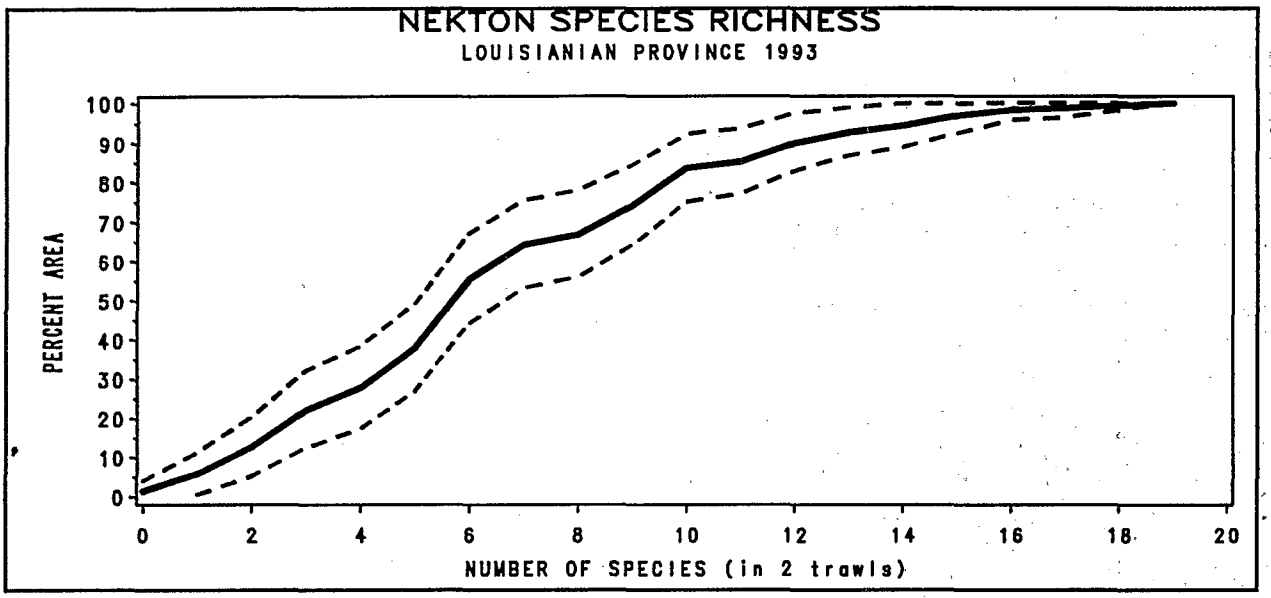


Figure 2-18. Cumulative distribution of number of fish species per trawl in the Louisianian Province estuaries in 1993 (–) and its associated 95% confidence interval (– –).

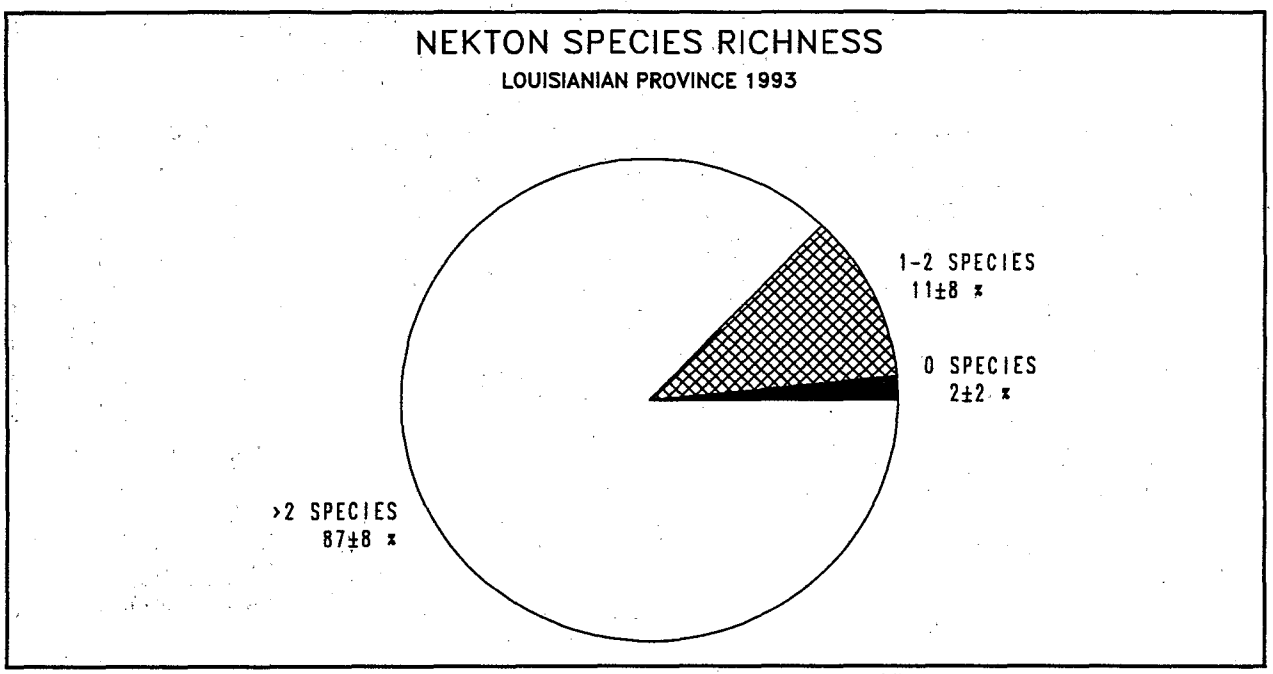


Figure 2-19. Percent of area of the Louisianian Province estuaries associated with the number of fish species per trawl categories in 1993.

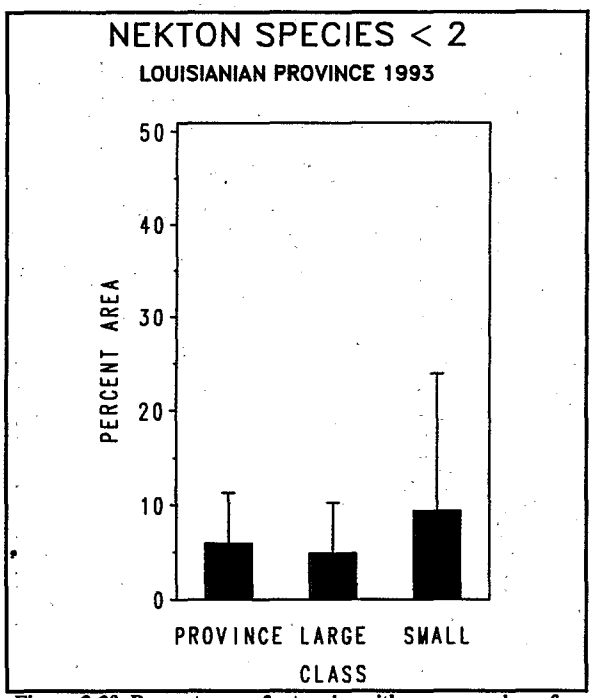


Figure 2-20. Percent area of estuaries with mean number of species per trawl < 2 species in large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

species collected throughout the province. Selecting 0 and < 2 species as comparative values for fish communities with low species abundance results in 2±2% of the province having no fish taken in multiple trawls, while 11±8% had nekton communities comprised of 1 or 2 species per trawl (Fig. 2-19). Areas having < 2 nekton species are primarily located in the small estuary class (Fig. 2-20).

2.1.6 TOTAL FINFISH ABUNDANCE

Finfish abundance is another indicator of the condition of biotic estuarine resources. Abundant nektonic organisms particularly in communities characterized by multiple species and feeding types suggest a productive estuarine food web. Finfish abundance in the trawls taken ranged from 0 to over 450 organisms per trawl (Fig. 2-21). Using 2 organisms/trawl and 5/trawl

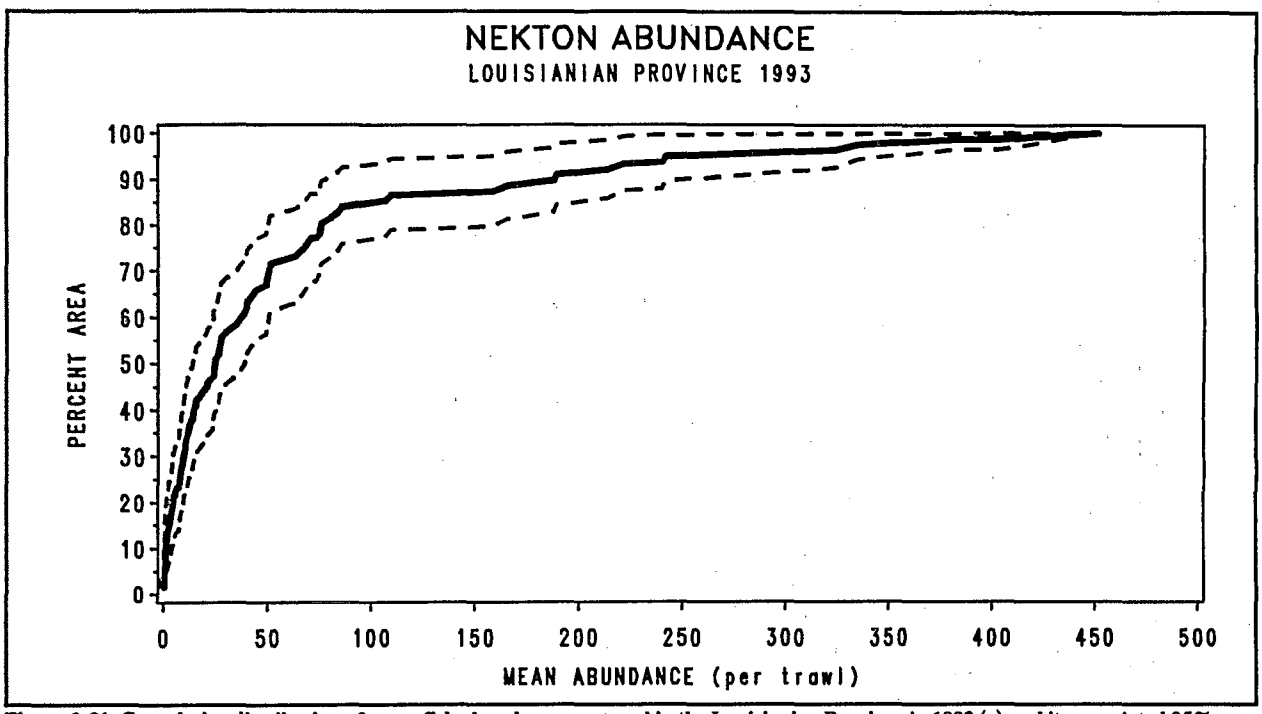


Figure 2-21. Cumulative distribution of mean fish abundance per trawl in the Louisianian Province in 1993 (–) and its associated 95% confidence interval (--).

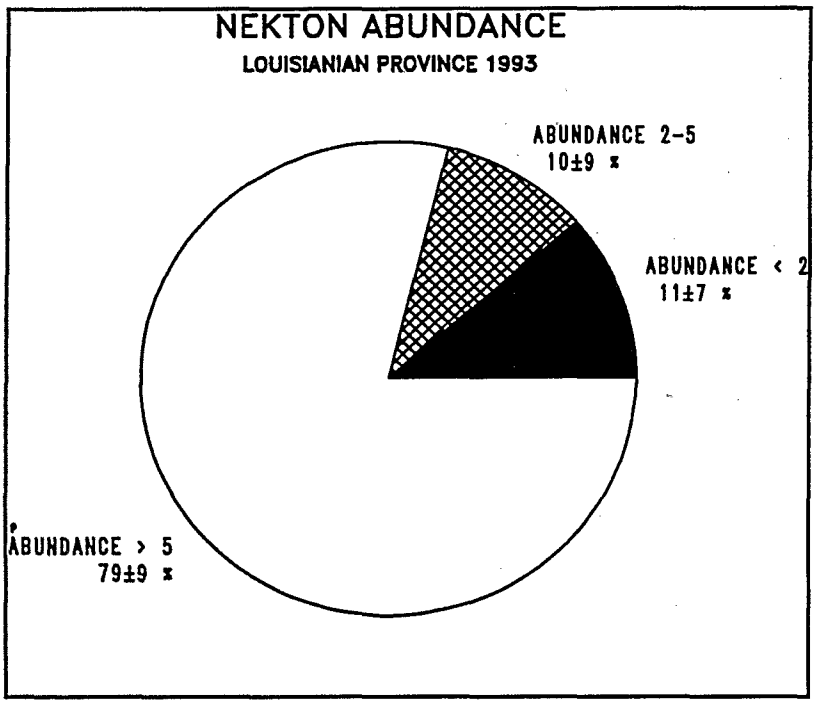


Figure 2-22. Percent area of the Louisianian Province estuaries associated with the mean fish abundance species categories in 1993.

as values representing low and marginal numbers of fish abundance respectively, 11±7% of Louisianian Province waters have low finfish abundances and an additional 10±9% have marginal abundance (Fig. 2-22). These areas of low abundance are primarily associated with small estuaries where 10±7% of waters in the class have finfish abundances < 2 (Fig. 2-23).

2.1.7 EXTERNAL GROSS PATHOLOGY

The frequency and type of external gross pathology associated with nekton taken in the fish trawls is an indicator of the overall condition of

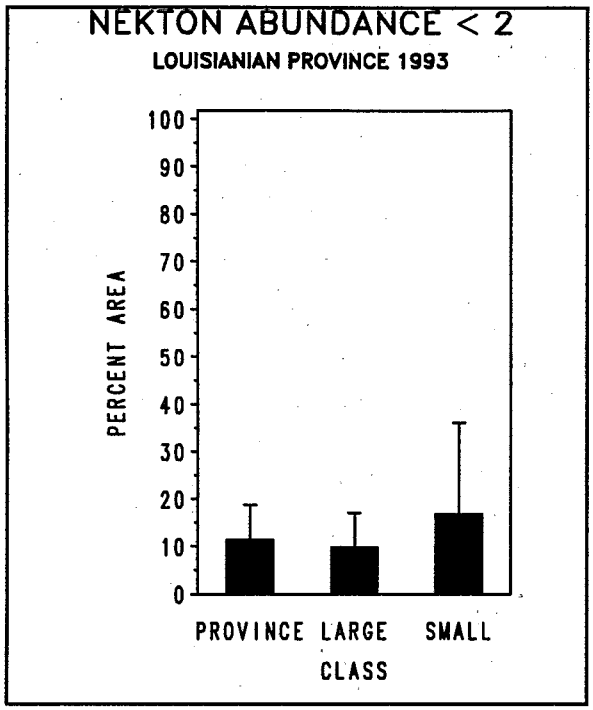


Figure 2-23. Percent area of estuaries with mean fish abundance per trawl < 2 species in large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

fish collected in trawls. All fish that were collected during the 1993 Louisianian Province Demonstration were examined by the field crews for external gross pathologies, such as tumors and lesions. Over 22,570 fish were examined for gross pathologies and a total of 97 external pathologies were noted. Three±3% of the area of the Louisianian Province produced trawls with > 2 pathologies/trawl (Fig. 2-24). Overall in the province, 0.43% of the fish examined had visible pathological disorders (Fig. 2-25). The prevalence of abnormalities for demersal and pelagic fish (0.4% and 0.3%, respectively) was about the same as the background level observed for all fish (0.43%). However, upper trophic level fish (e.g., piscivores) and commercially harvested species demonstrated a higher incidence of pathology (0.63% and 0.83%, respectively) (Fig. 2-25). Examples of upper trophic level fish are seatrouts, permits, and spadefish. Hardhead catfish, pinfish, and Atlantic croaker had visible

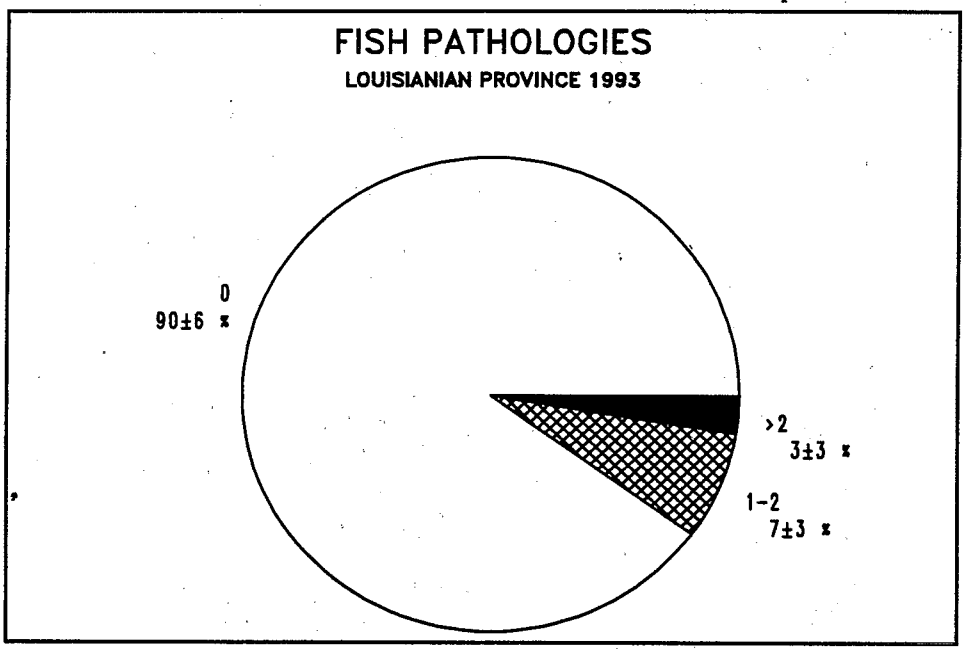


Figure 2-24. Percent of fish examined from the Louisianian Province estuaries associated with the number of external pathologies per trawl categories in 1993.

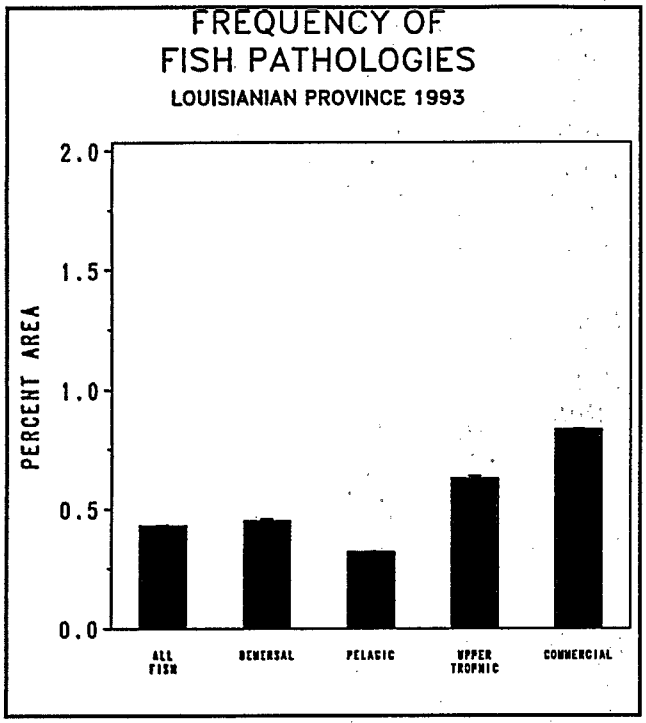


Figure 2-25. Percent of fish examined from the Louisianian Province with external pathologies by fish class, with 95% confidence interval.

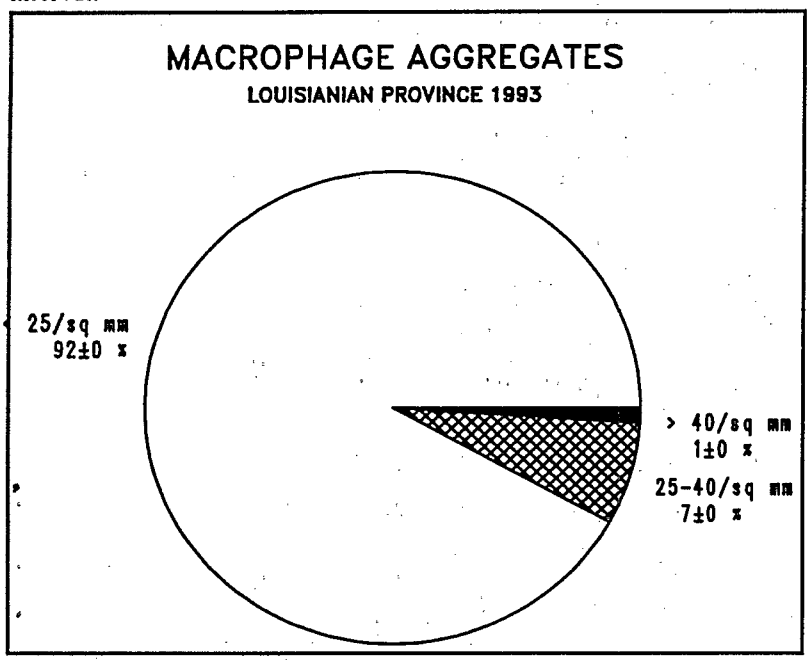


Figure 2-26. Percent area of fish examined from the Louisianian Province estuaries with number of macrophage aggregates per mm² in 1993.

pathology rates that were clearly higher than the observed background.

2.1.8 MACROPHAGE AGGREGATES

Pigment-bearing macrophages are a prominent feature of fish spleen, kidney, and liver (Agius 1980) and, in advanced telosts, they form discrete aggregations called macrophage aggregations (MAs) (Wolke *et al.* 1985). Suggested functions for these aggregates include the centralizations of foreign materials and cellular debris for destruction, detoxification, and/or reuse (Ferguson 1976; Ellis *et al.* 1976). It has been demonstrated that MAs' occurrence may vary depending on the size, nutritional state, or health of a particular fish (Agius 1979, 1980; Agius and Roberts 1981; Wolke *et al.* 1985) with the number and size of MAs increasing with age, starvation, and/or disease. Recent studies suggest that MAs may be sensitive histological indicators of fish health and environmental quality (Summers *et al.* 1993b, Blazer *et al.* 1993).

About 1±0% of the fish sampled in the Louisianian Province contained macrophage aggregate concentrations > 40/mm² (Fig. 2-26). The distribution of percent area occupied by macrophage aggregates is similar to the distribution of number of aggregates with the proportion of the fish populations showing > 5% of spleen area covered by aggregates being 0.1% (Fig. 2-27). These figures do not suggest that these stressed communities are solely the result of anthropogenic

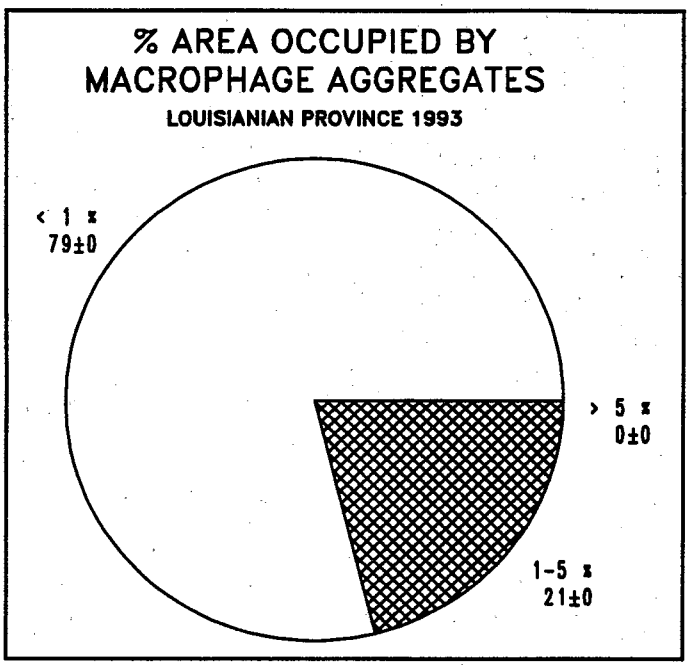


Figure 2-27. Cumulative distribution of percent area of spleen occupied by macrophage aggregates in fish examined from the Louisianian Province in 1993 (associated 95% confidence interval too narrow to portray).

influences. Some of the high level of macrophage aggregates described could be the result of natural conditions (e.g., naturally induced hypoxia, low food supply). However, 24% of the differences observed between locations with fish with high or low levels of macrophage aggregates were associated with tissue contaminants, mercury and hexachlordane, as well as low dissolved oxygen concentration. The associations for the remaining 76% of the differences were either unknown or related to habitat variations.

2.1.9 MARINE DEBRIS

The presence of marine debris is one of the obvious indicators of estuarine "degradation" from a human use perspective. The presence of trash in the water and along the bottom reduces the value of the water body as a recreational resource and may have ecological effects as well. During the 1993 Louisianian Province Demonstration the presence of marine debris was noted in bottom sediments and in the water column, and the type of the trash was determined (e.g., plastic, anthropogenic wood, metal, glass, etc.). In 1993, over 11±7% of the surface area of the Louisianian Province contained at least one item of marine debris. The estuarine class with the largest proportion of sediment having marine debris was the small estuaries with 14±18% coverage. Large estuaries had 10±7% of their sediments containing marine debris, respectively (Fig. 2-28).

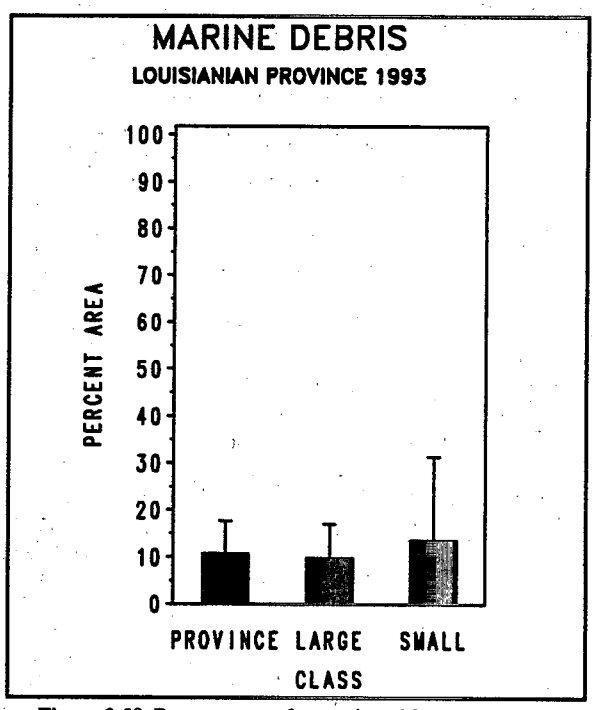


Figure 2-28. Percent area of estuaries with presence of marine debris in sediments in large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

2.1.10 WATER CLARITY

Another "social" or human use criterion for good condition of an estuary is water clarity and the lack of noxious odors. At each sampling site during the Demonstration odors were noted when present; however, no sites were classified as having any unusual odor. Water clarity was measured using a comparison of surface ambient light, photosynthetically active radiation (PAR), and the amount of light reaching any depth (measurements were taken every meter to the bottom). For the sake of relative comparison, the proportion of incident light reaching 1 meter was used as the standard for all sites (i.e., all sites were at least 1 m in depth). The proportion of light transmittance at 1 meter ranged from near 0% to about 62% (Fig. 2-29). Using 10% transmittance (i.e., 10% of surface light) as a measure of "turbid" clarity (i.e., cannot see your hand in front of your face), 18±8% of the Louisianian Province experienced turbid water clarity (Fig. 2-30). Alternatively, using 25% transmittance as a measure of moderate clarity (cannot see your toes in waist deep water), resulted in 45±12% of the Louisianian Province with water clarity that could not pass this visual test. The poorest water clarity occurred in small estuaries with 22±18% (Fig. 2-31).

2.1.11 FISH TISSUE CONTAMINANTS

Three sets of target species were examined for the concentrations of selected contaminants in edible flesh. These were: shrimp (brown and white), Atlantic croaker, and catfish (hardhead, gafftopsail, and blue catfish). The edible portions of the shrimps were defined as the tail meat with the shell removed, as the fillet with skin for Atlantic croaker, and as the fillet without skin for the catfish. All samples

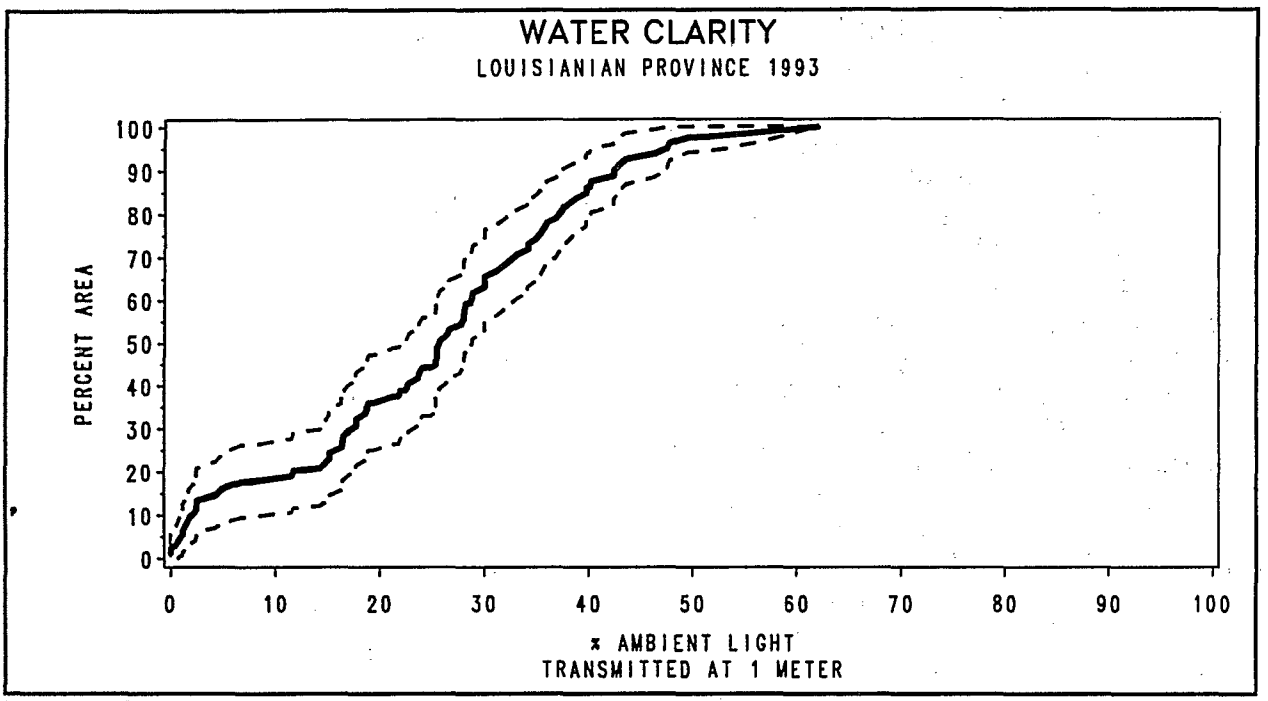


Figure 2-29. Cumulative distribution of water clarity as measured as percent of surface light reaching a depth of 1 m in the Louisianian Province in 1993 (–) and its associated 95% confidence interval (--).

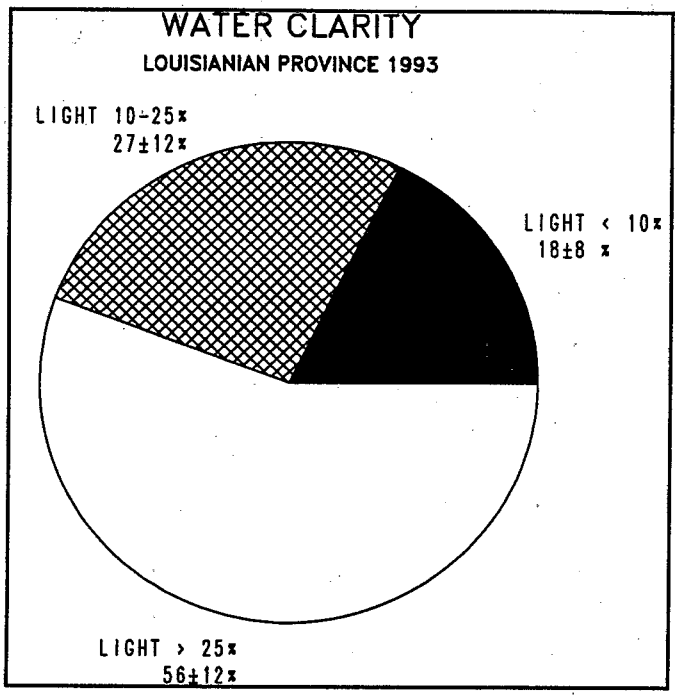


Figure 2-30. Percent area of the Louisianian Province estuaries associated with light categories in 1993.

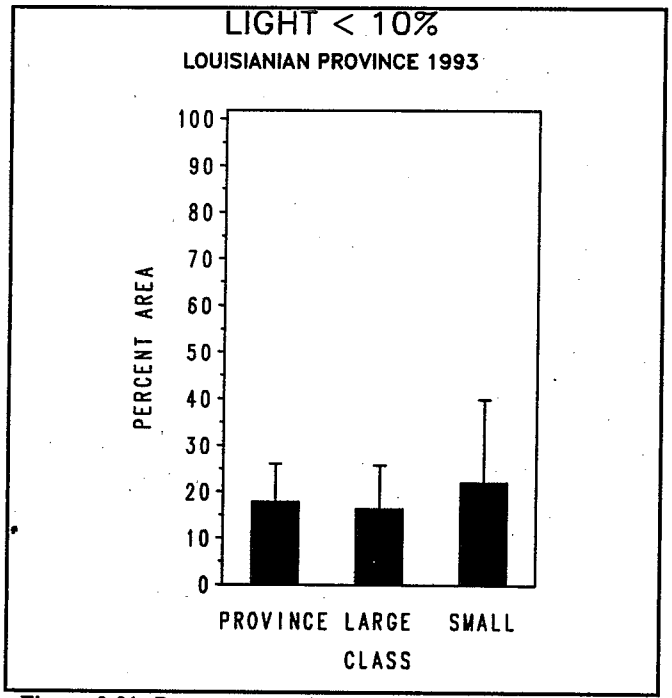


Figure 2-31. Percent area of estuaries with less than 10% ambient light penetrating to a depth of 1.0 meter in large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

represented a composite of 3 to 10 individuals collected from a single site. Initially, criteria levels for pesticides, PCBs, and mercury were taken from USFDA standards (USFDA 1982, 1984) with the exception of hexachlorobenzene, lindane, endosulfan, and trans-nonachlor for which U.S. standards were not available. Swedish standards were substituted for hexachlorobenzene and lindane (Nauen 1983). Other than mercury, no USFDA standards were available for metals; therefore, metals criteria reflect the means of international limits (Nauen 1983).

This comparison of fish population contaminant distributions to FDA action limits represents a slight misuse of these criteria. The EMAP-Estuaries data for the Louisianian Province do not represent only market-size fish (i.e., most fish were less than market size) or those fish transported across state lines for sale. However, the FDA action limits do provide a convenient point of comparison to track potential trends in tissue residue levels in juvenile fish.

No pesticide, or PCB concentrations exceeded the specified criteria for shrimp (Table 2-1). The highest concentration of an organic contaminant found was 14.6 ppb total PCBs (compared to the standard of 2000). Heptachlor and aldrin were the pesticides found in highest concentrations in shrimp tailmeat at 8 and 4.8 ppb respectively. This represents 2.7% of the FDA limit for heptachlor and 1.6% of the limit for Aldrin. A total of 9% of the shrimp exceeded 2 ppm arsenic, 15 ppm copper, and 1 ppm mercury respectively. Four percent exceeded 1 ppm selenium.

No pesticide or PCB concentrations exceeded the specified FDA action limits for Atlantic croaker (Table 2-2). DDD, endrin and mirex

Contaminant	Observed Range	Criterion[1]	Proportion Exceeding Criterion
Pesticides (ng/g wwt)			
DDD	ND	5000	0%
DDE	0-2.4	5000	0%
DDT	0-2.2	5000	0%
Aldrin	0-4.8	300	0%
Chlordane	ND	300	0%
Dieldrin	ND	300	0%
Endosulfan	0-3.2	NA[2]	U[3]
Endrin	0-0.0	300	0%
Heptachlor	0-8.0	300	0%
Heptachlor Epoxide	0-2.5	300	0%
Hexachlorobenzene	0-4.5	200	0%
Lindane	0-0.0	200	0%
Mirex	0-0.0	100	0%
Toxaphene	0-0.0	5000	0%
Trans-Nonachlor	0-1.5	NA	U
PCBs (ng/g wwt)			
21 Congeners	0-12.7	500	0%
Total PCBs	0-14.6	2000	0%
Heavy Metals (µg/g wwt)			
Aluminum	2.6-56.2	NA	U
Arsenic	0.18-4.1	2	9%
Cadmium	0-0.2	0.5	0%
Chromium	0.1-0.3	1	0%
Copper	5.9-18.3	15	9%
Lead	0-0.1	0.5	0%
Mercury	0-1.02	1	9%
Nickel	0.03-0.18	NA	U
Selenium	0.03-0.07	1	4%
Silver	0-0.05	NA	U
Tin	0-0	NA	U
Zinc	14.3-18.7	60	0%

[1] Criteria were selected from FDA-established limits for pesticides and PCBs (USFDA 1982, 1984) except hexachlorobenzene and lindane which are based on Swedish limits (Nauen 1983); no FDA limits exist for metals other than mercury; metals criteria reflect means of international limits (Nauen 1983).
[2]NA = Not available
[3]U = Unknown because no criterion level available
[4]ND = Not Detected

Table 2-1. Overview of the contaminant levels observed in edible flesh of brown shrimp and white shrimp.

Contaminant	Observed Range	Criterion[1]	Proportion Exceeding Criterion
Pesticides (ng/g wwt)			
DDD	0-49.4	5000	0%
DDE	0-8.9	5000	0%
DDT	0-6.5	5000	0%
Aldrin	0-2.8	300	0%
Chlordane	0-2.4	300	0%
Dieldrin	0-2.0	300	0%
Endosulfan	0-2.3	NA[2]	U[3]
Endrin	0-11.1	300	0%
Heptachlor	0-0	300	0%
Heptachlor Epoxide	0-1.7	300	0%
Hexachlorobenzene	0-6.1	200	0%
Lindane	0-0	200	0%
Mirex	0-10.5	100	0%
Toxaphene	0-0	5000	0%
Trans-Nonachlor	0-2.3	NA	U
PCBs (ng/g wwt)			
21 Congeners	0-91.3	500	0%
Total PCBs	0-95.3	2000	0%
Heavy Metals (µg/g wwt)			
Aluminum	0-36.1	NA	U
Arsenic	0-7.0	2	5%
Cadmium	0-0.18	0.5	0%
Chromium	0.02-1.1	1	1%
Copper	0-25.4	15	1%
Lead	0-1.6	0.5	2%
Mercury	0-0.7	1	0%
Nickel	0-1.0	NA	U%
Selenium	0-.12-1.4	1	2%
Silver	0-0.14	NA	U%
Tin	0-1.1	NA	U%
Zinc	1-14.6	60	0%

[1]Criteria were selected from FDA-established limits for pesticides and PCBs (USFDA 1982, 1984) except hexachlorobenzene and lindane which are based on Swedish limits (Nauen 1983); no FDA limits exist for metals other than mercury; metals criteria reflect means of international limits (Nauen 1983).
[2]NA = Not available
[3]U = Unknown because no criterion level available

Table 2-2. Overview of the contaminant levels observed in edible flesh of Atlantic croaker .

represented the highest fillet pesticide organic residues found in Atlantic croaker at 49.4, 11.1 and 10.5 ppb, respectively. These concentrations represent < 1%, 3.7% and 10.5% of the action limits for these contaminants. Heavy metal criteria for arsenic (5%), cadmium (4%), lead (2%), selenium (2%), chromium (1%), and copper (1%) were exceeded in croaker.

No pesticide or PCB concentrations exceeding the specified FDA action limits were found in marine catfish (Table 2-3). Several heavy metals exceeded the international standards with 62% of marine catfish in excess of 2 ppm arsenic, 1% in excess of 1 ppb chromium, 1% in excess of 1 ppm mercury, and 5% in excess of 0.5 ppm lead.

Organic and inorganic forms of arsenic were not distinguished by our analyses. The high percentage of catfish exceeding the standard value may not pose a problem, as the organic form of arsenic is not readily bioavailable.

2.1.12 INTEGRATION OF ESTUARINE CONDITIONS

The overall condition of the estuaries in the Louisianian Province has been summarized by combining the benthic index, marine debris, water clarity and tissue contaminants, weighted equally. This single value includes an index of societal values (aesthetics) and estuarine biotic integrity based on benthic assemblages and fish health condition (Fig. 2-32). Indicators relating to biotic integrity and aesthetics were used to estimate overall environmental conditions in the estuaries. Forty-six percent (±11%) of the estuarine area in the Louisianian Province showed evidence of degraded biological resources or was impaired with respect to its ability to support activities valued by society (Fig.

Contaminant	Observed Range	Criterion[1]	Proportion Exceeding Criterion
Pesticides (ng/g wwt)			
DDD	0-18.5	5000	0%
DDE	0-104.8	5000	0%
DDT	0-20.7	5000	0%
Aldrin	0-22.5	300	0%
Chlordane	0-4.2	300	0%
Dieldrin	0-83.6	300	0%
Endosulfan	ND	NA[2]	U[3]
Endrin	0-1.9	300	0%
Heptachlor	0-2.6	300	0%
Heptachlor Epoxide	0-1.6	300	0%
Hexachlorobenzene	0-6.3	200	0%
Lindane	0-2.0	200	0%
Mirex	0-2.4	100	0%
Toxaphene	0-0	5000	0%
Trans-Nonachlor	0-6.1	NA	U
PCBs (ng/g wwt)			
21 Congeners	0-20.6	500	0%
Total PCBs	0-56.7	2000	0%
Heavy Metals (µg/g wwt)			
Aluminum	0-88.6	NA	U
Arsenic	0-39.9	2	62%
Cadmium	ND	0.5	0%
Chromium	0-1.04	1	1%
Copper	0-11.6	15	0%
Lead	0-6.5	0.5	5%
Mercury	0-1.6	1	1%
Nickel	0-30.5	NA	U
Selenium	0.1-0.6	1	2%
Silver	0-0.1	NA	U
Tin	0-0.1	NA	U
Zinc	4.8-28.4	60	0%

[1] Criteria were selected from FDA-established limits for pesticides and PCBs (USFDA 1982, 1984) except hexachlorobenzene and lindane which are based on Swedish limits (Nauen 1983); no FDA limits exist for metals other than mercury; metals criteria reflect means of international limits (Nauen 1983).
[2]NA = Not available
[3]U = Unknown because no criterion level available
[4]ND = Not Detected

Table 2-3. Overview of the contaminant level observed in edible flesh of catfish .

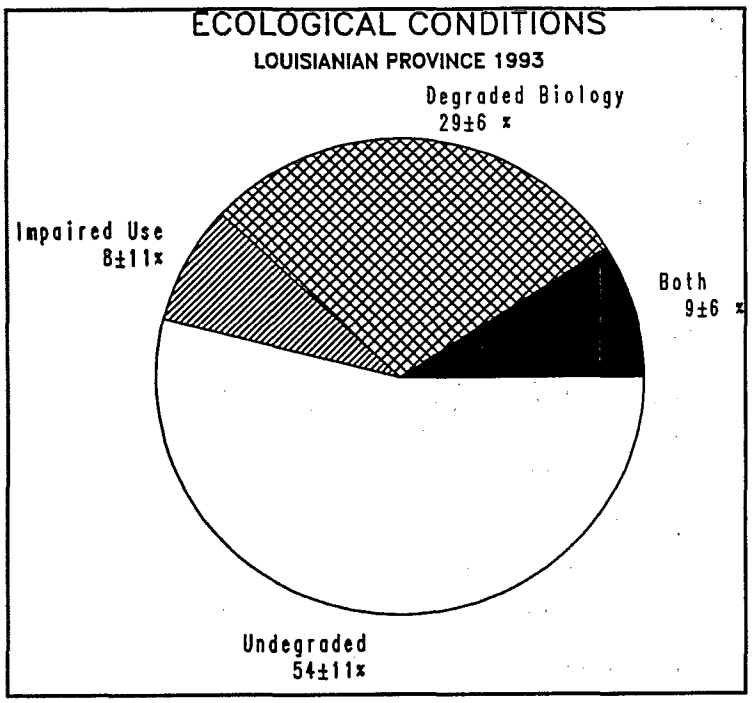


Figure 2-32. Percent area of the Louisianian Province estuaries in 1993 associated with degraded biology and impaired use.

2-32). Of the 25,725 km^2 of estuarine surface area in the Louisianian Province, 11,833±2,830 km^2 were potentially degraded.

The location of degraded biological resources were sometimes different from those having aesthetic problems. Both sets of conditions were found in 9±6% of the estuarine area, whereas degraded biological conditions alone were found in 29±6% of the province and degraded human use alone was found in 8±11% of the Louisianian Province.

2.2 EXPOSURE INDICATORS

Exposure indicators have historically been the mainstay of environmental monitoring programs. Indicators of pollutant exposure measured during the 1993 Louisianian Province Demonstration were dissolved oxygen concentration (instantaneous and continuous), sediment toxicity (*Ampelisca abdita and Mysidopsis bahia*), and sediment contaminants (27 alkanes, 43 PAHs, 25 pesticides, 20 PCB congeners, 4 butyltins, and 15 heavy metals).

2.2.1 DISSOLVED OXYGEN (INSTANTANEOUS)

As stated earlier, dissolved oxygen (DO) concentration is important because it is a fundamental requirement of populations of benthos, fish, shellfish, and other aquatic biota. DO was measured in two ways during the 1993 Louisianian Province Demonstration: instantaneous point measures at 1-m depth intervals during sampling and deployed continuous recordings of dissolved oxygen for a 24-hour period at a depth of 0.5m above the bottom.

The cumulative distribution functions of instantaneous dissolved oxygen concentrations at depth intervals showed, as would be expected, an increased tendency toward lower concentrations with depth (Figures 2-33 through 2-37). Minimum DO concentrations derived from province-wide instantaneous estimates decreased from 4.8 ppm at the surface to 0.9 ppm at 1 m, 0.3 ppm at 2 m, 0.2 ppm at 3 m, and 0.2 at the bottom. The minimum values show this steady decline with depth reflecting the stratified nature of some estuaries. However, the median values change very little (ranging from 7.0 at the surface to 5.8 at the bottom) suggesting that most estuaries in the Louisianian Province are well mixed. Surface dissolved oxygen concentrations were rarely observed to

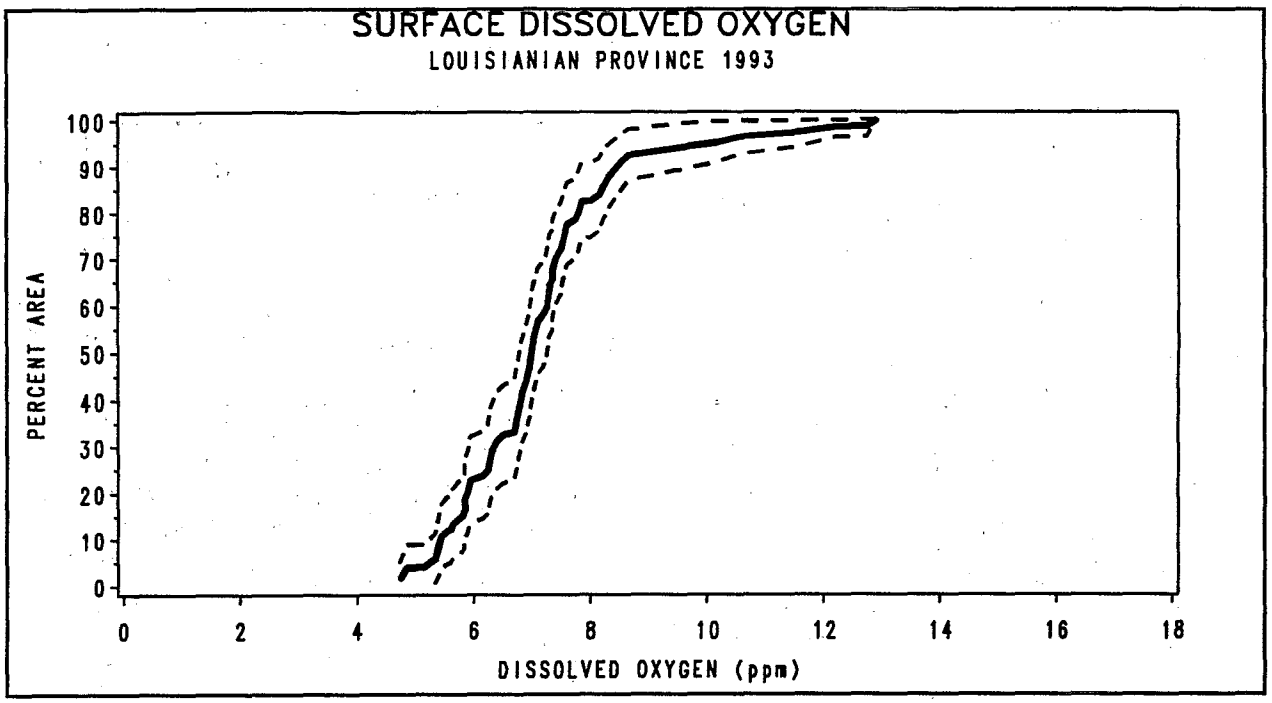


Figure 2-33. Cumulative distribution of surface dissolved oxygen concentration in the Louisianian Province in 1993 (–) and its associated 95% confidence interval (--).

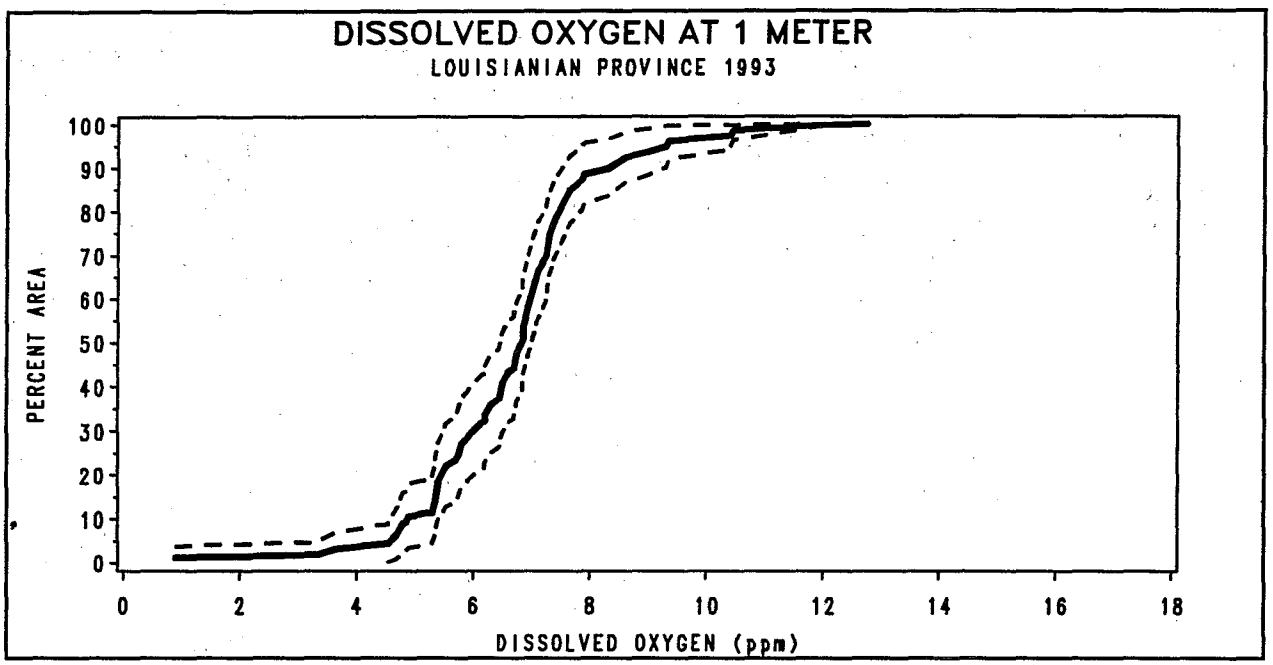


Figure 2-34. Cumulative distribution of dissolved oxygen concentration at a depth of 1 m in the Louisianian Province in 1993 (–) and its associated 95% confidence interval (--).

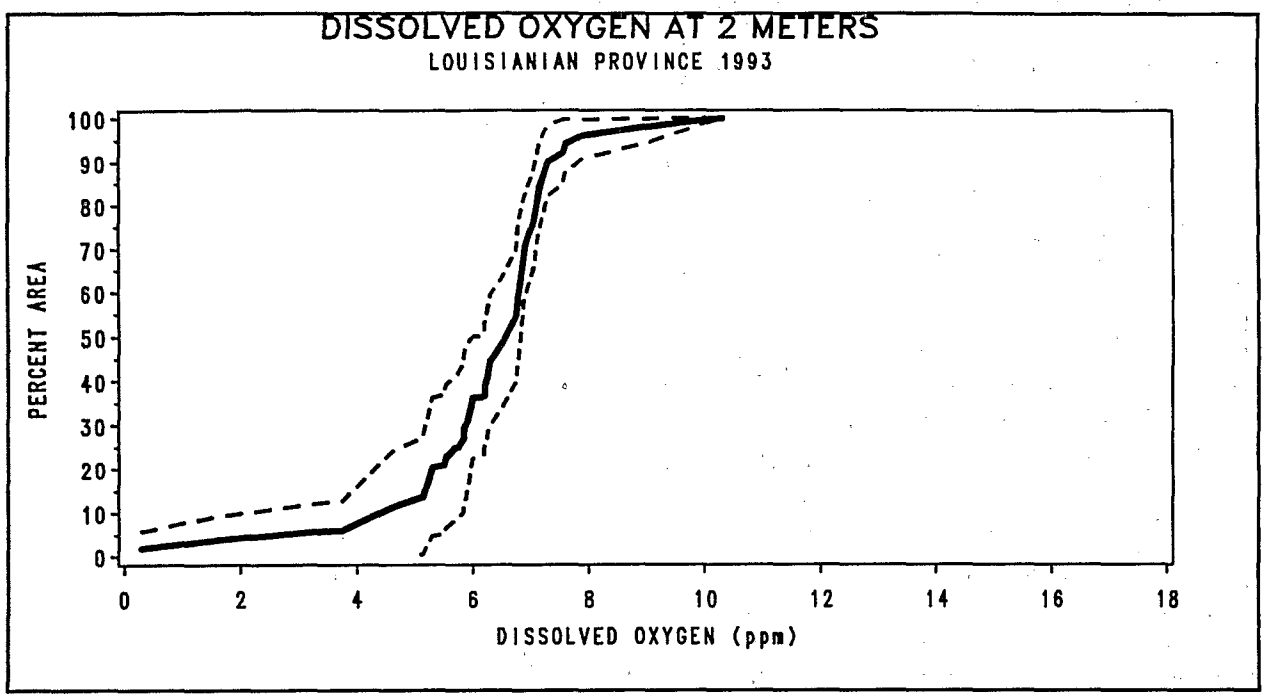


Figure 2-35. Cumulative distribution of dissolved oxygen concentration at a depth of 2 m in the Louisianian Province in 1993 (–) and its associated 95% confidence interval (--).

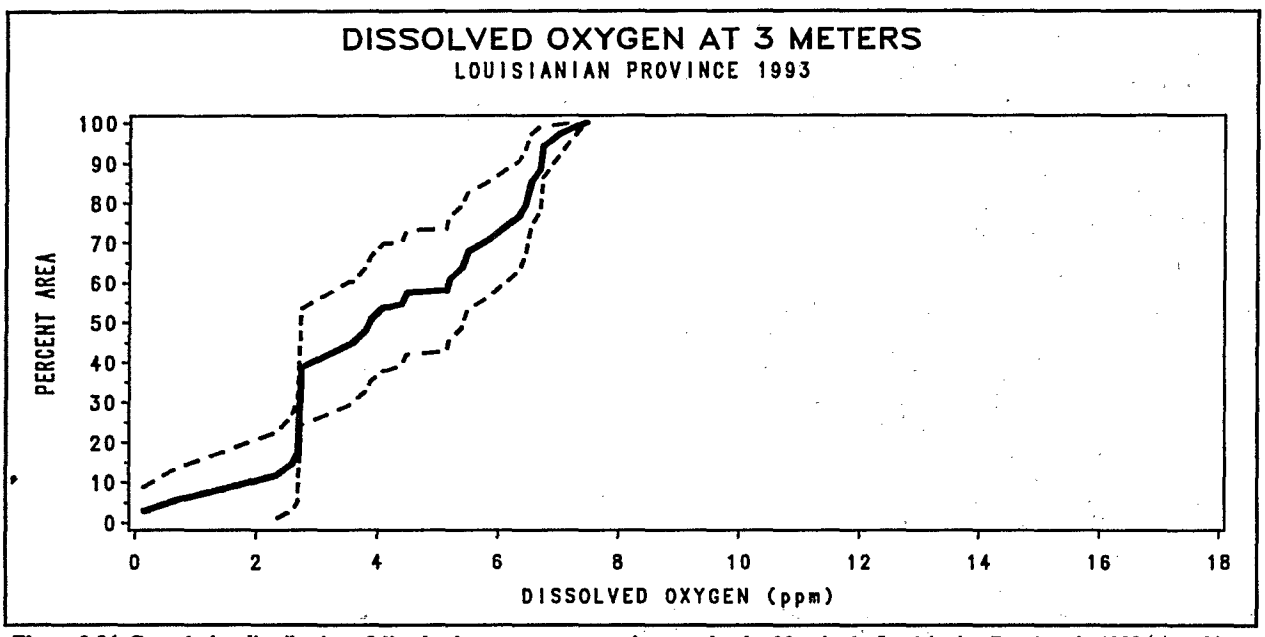


Figure 2-36. Cumulative distribution of dissolved oxygen concentration at a depth of 3 m in the Louisianian Province in 1993 (–) and its associated 95% confidence interval (--).

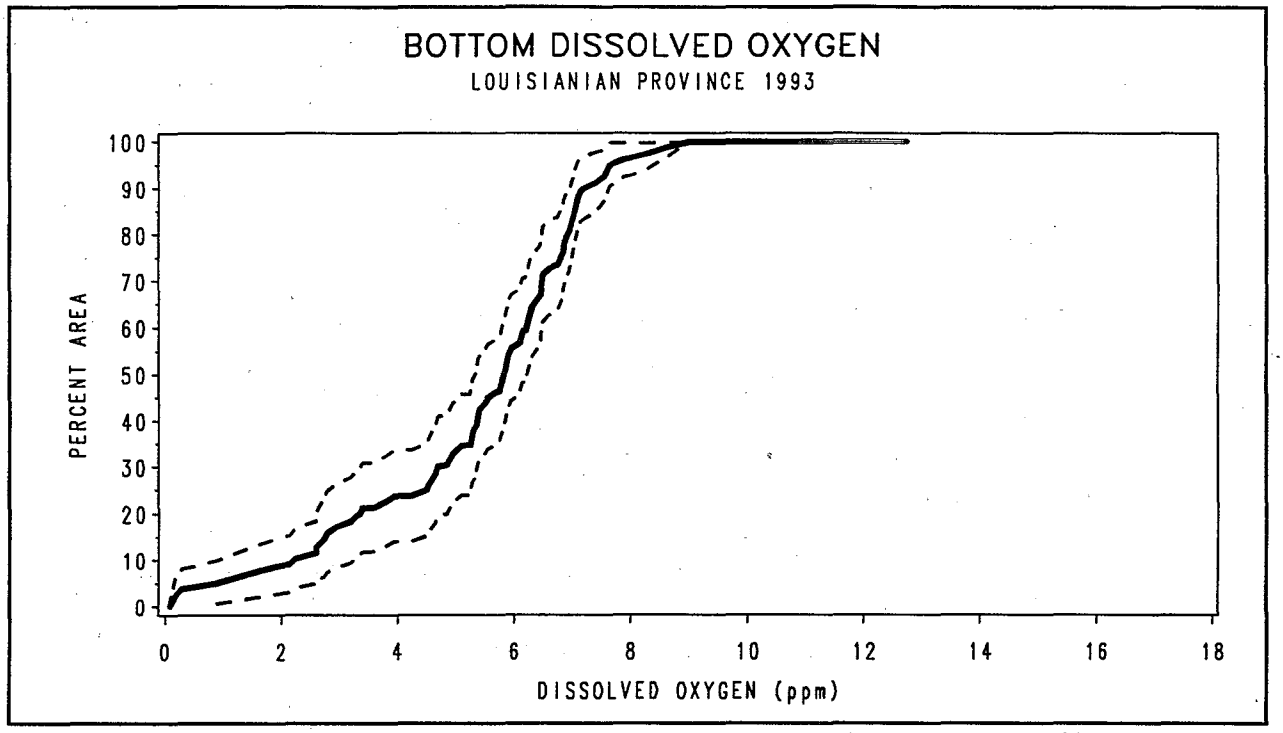


Figure 2-37. Cumulative distribution of bottom dissolved oxygen concentration in the Louisianian Province in 1993 (–) and its associated 95% confidence interval (--).

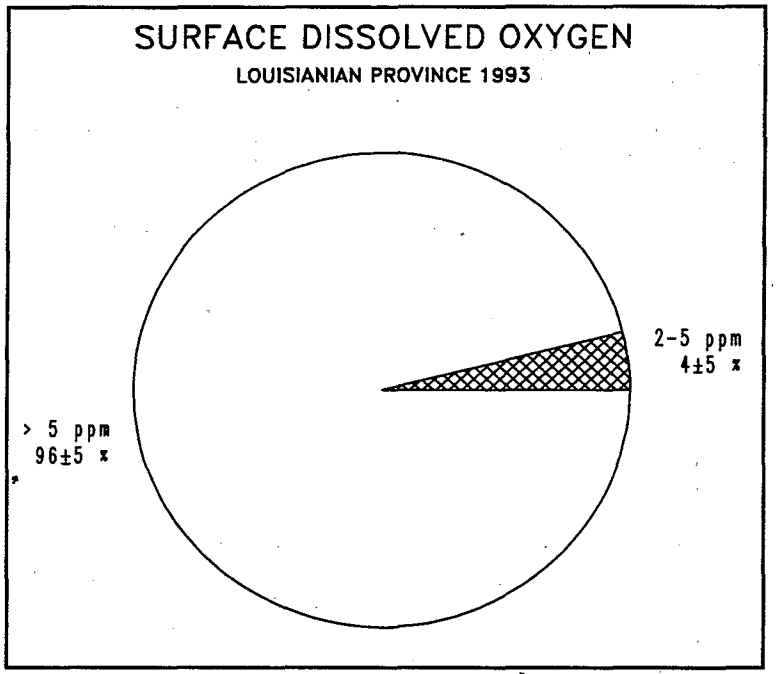


Figure 2-38. Percent area of the Louisianian Province estuaries associated with surface dissolved oxygen categories in 1993.

be below 5 ppm during the daylight sampling (Fig. 2-38) while bottom DO concentrations were below 5 ppm for 32±11% of the province and below 2 ppm for 7±6% of the province (Fig. 2-39). Bottom dissolved oxygen concentrations < 5 ppm were seen in both estuarine classes with large estuaries displaying the greatest extent at 34±12% of the class resources, and small estuaries at 30±25% (Fig. 2-40). However, the proportion of class resources that experienced DO concentrations < 2 ppm were almost exclusively within the large estuary class where 10±7% were characterized by these conditions. Small estuaries had virtually no incidence of DO concentrations below 2 ppm (1±1%) during daylight sampling (Fig. 2-41).

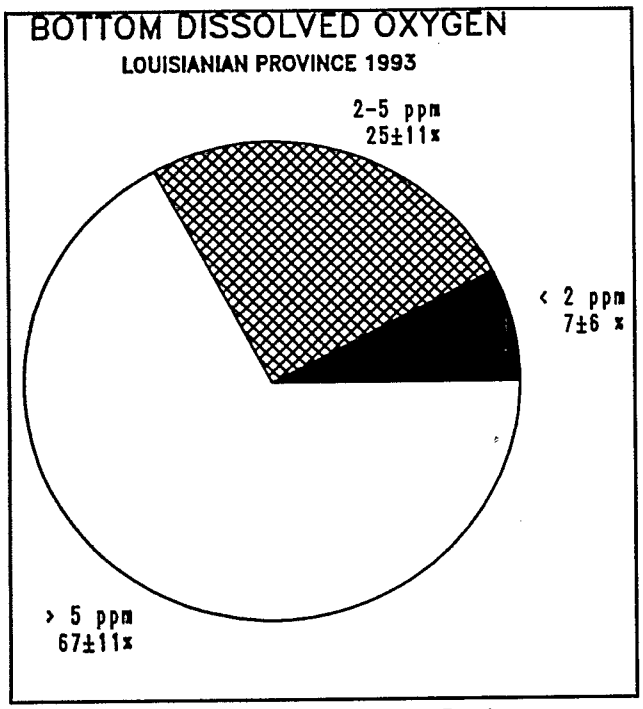


Figure 2-39. Percent area of the Louisianian Province estuaries associated with bottom dissolved oxygen categories in 1993.

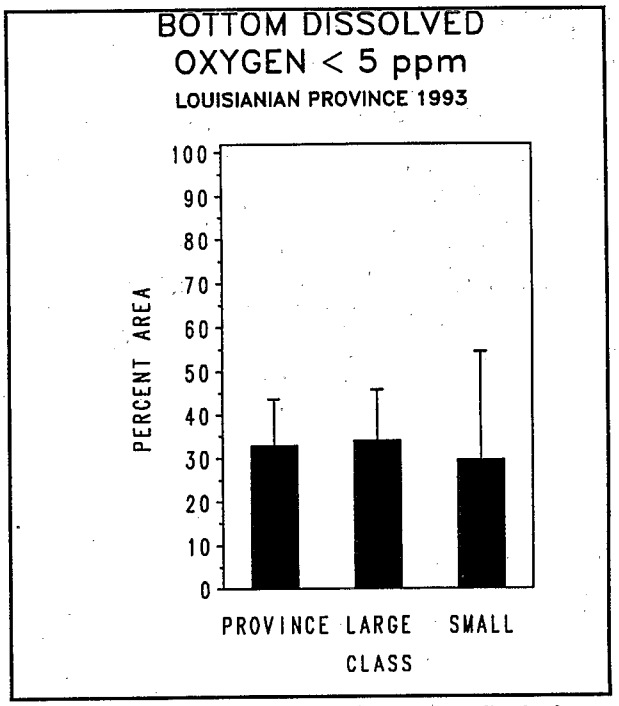


Figure 2-40. Percent area of estuaries with bottom dissolved oxygen < 5 ppm in large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

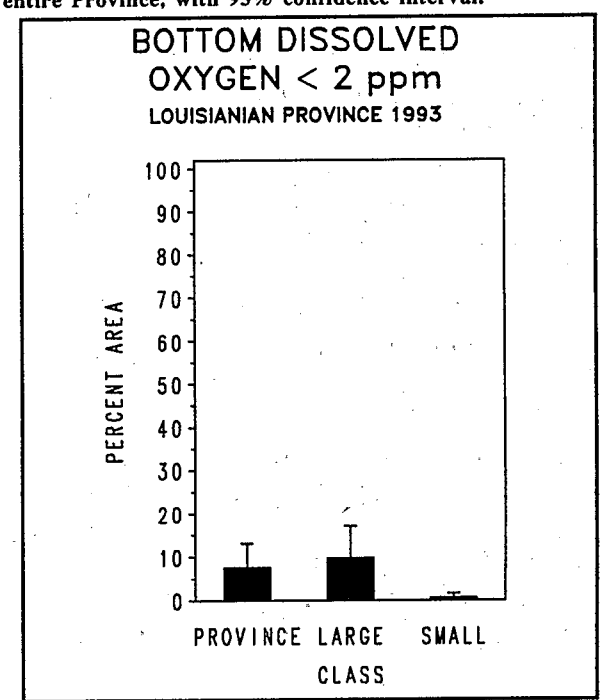


Figure 2-41. Percent area of estuaries with bottom dissolved oxygen < 2 ppm in large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

2.2.2 DISSOLVED OXYGEN - (CONTINUOUS)

Unlike the instantaneous measures, the continuous dissolved oxygen concentration measurements provide a more complete picture of the DO conditions within an estuary by including periods of high water column and sediment respiration (i.e., night). The continuous measures were collected because earlier studies (Summers and Engle 1993) showed that a combination of daily minimum DO concentration and the incidence of DO concentrations < 2 ppm for > 20% of the deployed period could be used to successfully characterize an estuary as "good" or "hypoxic" with regard to index period DO conditions.

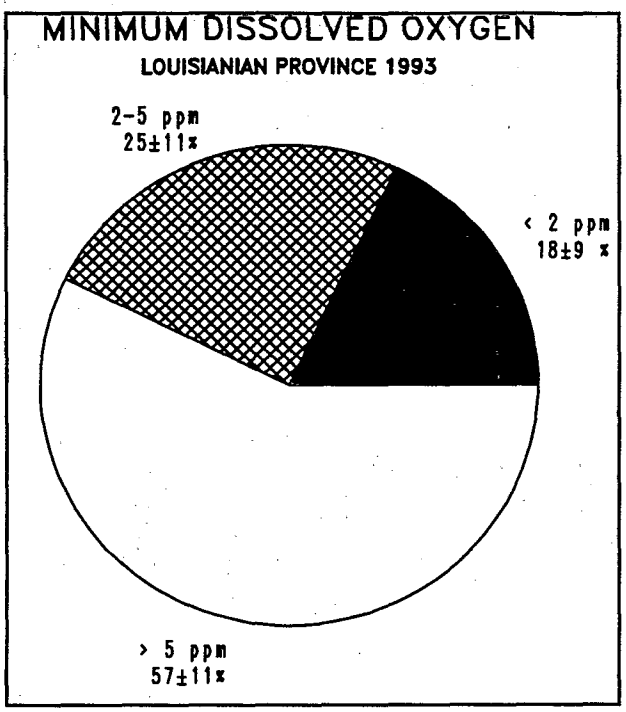


Figure 2-42. Percent area of the Louisianian Province estuaries associated with minimum bottom dissolved oxygen (continuous sampling) categories in 1993.

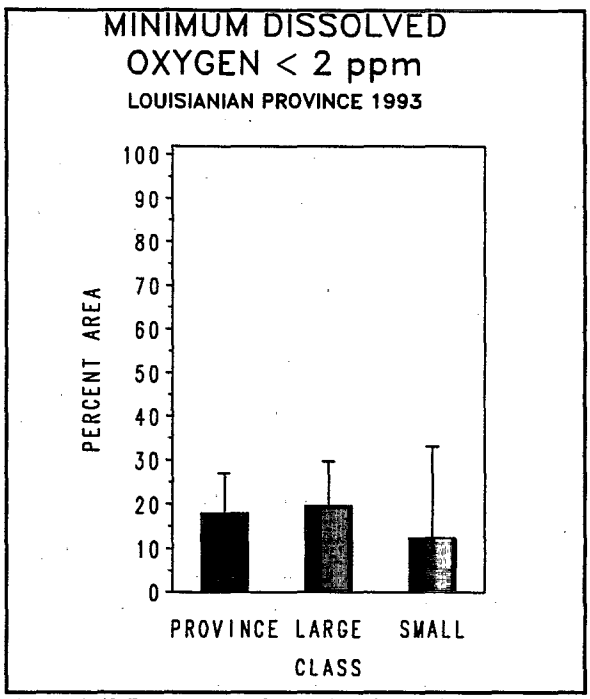


Figure 2-43. Percent area of estuaries with minimum bottom (continuous sampling) dissolved oxygen < 2 ppm in large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

Minimum DO concentrations resulting from continuous recordings showed that 18±9% of the province experienced DO conditions below 2 ppm while 43±11% of the province had minimal dissolved oxygen concentrations < 5 ppm (Fig. 2-42). Based on the above estimation technique, this represents only a 1% increase in the estuarine bottom area experiencing low DO conditions based on instantaneous measurements during daylight hours. Thus in 1993, only an additional 1% of province estuaries experience cyclic DO conditions so that high concentrations are observed during the day and concentrations < 2 ppm are observed at night. Similarly, an additional 13% of estuaries in the Louisianian Province experience DO conditions < 5 ppm at night. In 1993, where lower DO conditions were predominant in large estuaries during daylight hours, continuous measurements also showed that large estuaries experience DO conditions below 2 ppm more frequently than other estuaries (Fig. 2-43). Thus, unlike the conditions observed in 1991, DO conditions in 1993 rarely portrayed extreme cyclic patterns showing DO conditions < 2 ppm only at night. Systems experiencing low bottom DO conditions continuously (day and night) include about 5% of the large estuarine surface area within the province (e.g., Mobile Bay, parts of Chandeleur Sound).

All estuaries exhibit DO cycling to some degree. However, the cyclic nature described here suggests wide amplitude changes in concentrations from day to night in many small estuaries although few estuaries cycle lower than 2 ppm. Examination of the duration of low

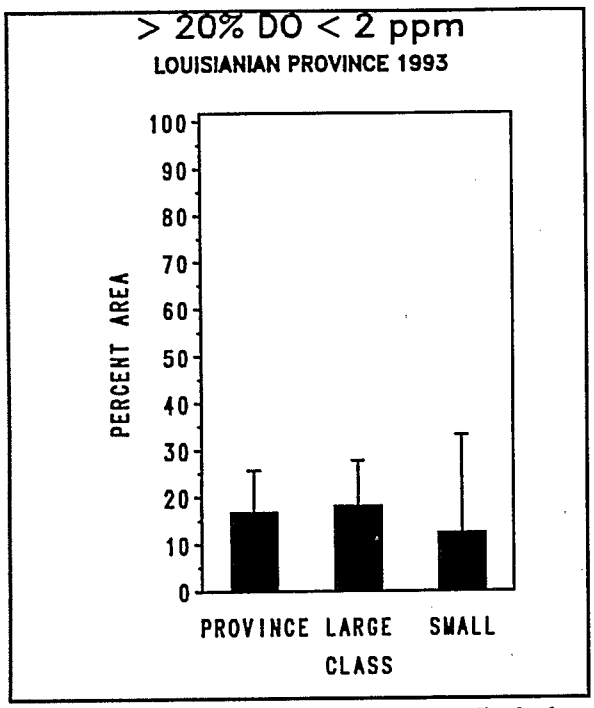


Figure 2-44. Percent area of estuaries with bottom dissolved oxygen < 2 ppm for greater than 20% of the observations in large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

DO conditions in the Louisianian Province showed that 17±9% of the province exhibited DO concentrations below 2 ppm for greater than 5 hours during the day (20% of time). These measurements were seen primarily in the large estuarine class (Fig. 2-44).

2.2.3 SEDIMENT TOXICITY - AMPELISCA ABDITA

Sediment toxicity tests were performed on the composited surface sediments collected from each sampling site. Tests included a standard 10-day acute test (Swartz et al. 1985; ASTM 1990) using the tube-dwelling amphipod, *Ampelisca abdita*. About 1±2% of the sediments collected in the Louisianian Province were toxic to the amphipods (Fig. 2-45). In these sediments, mortality rates were >20% higher than, and significantly higher than, those observed in the controls. The estuarine sampling class with the largest proportion of toxic sediment was the large estuary class (1.6±3.2%) while small estuaries showed toxicity to a lesser extent (0.9±1.6%) (Fig. 2-46). On a province-wide scale, large estuaries contributed 299 km^2 with small estuaries contributing 67.5 km^2 of toxic sediments.

2.2.4 SEDIMENT TOXICITY - MYSIDOPSIS BAHIA

Because *Ampelisca abdita* is relatively uncommon in the estuaries of the Louisianian Province and had to be purchased and

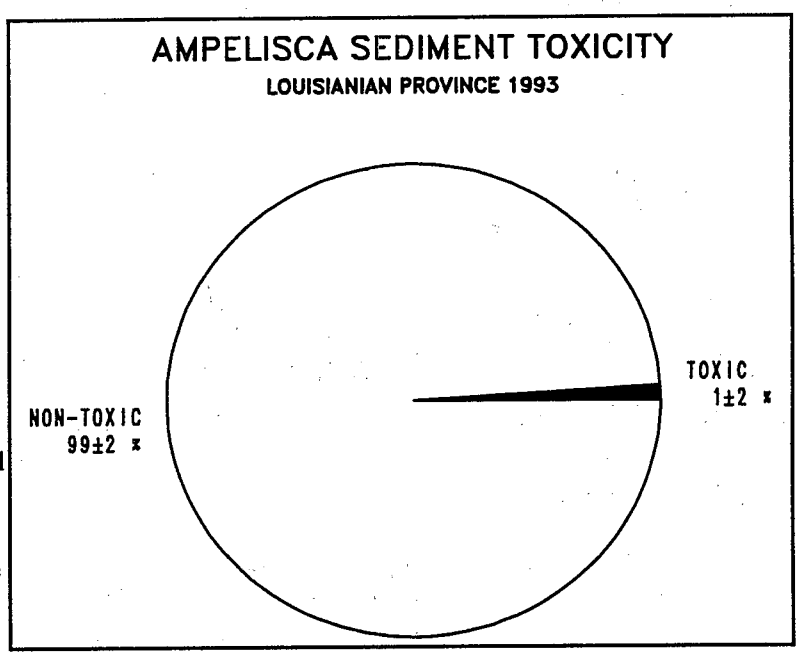


Figure 2-45. Percent area of the Louisianian Province estuaries associated with Ampelisca sediment toxicity categories in 1993.

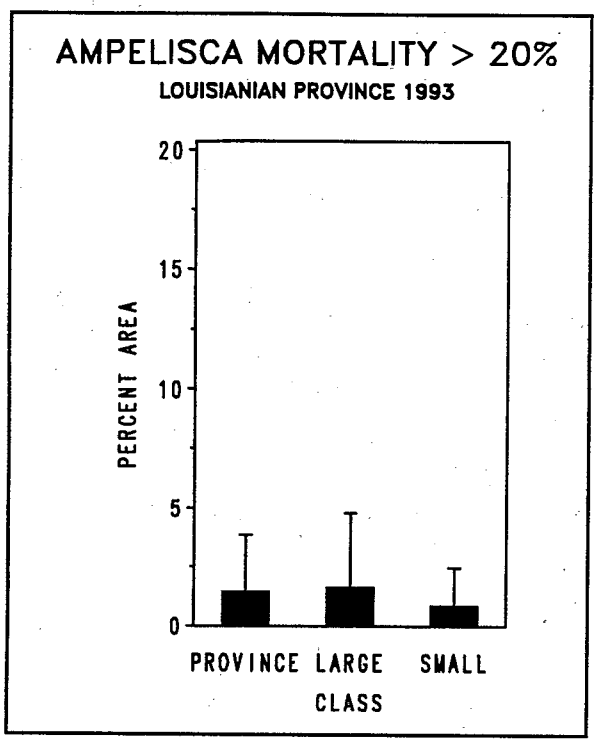


Figure 2-46. Percent area of estuaries with *Ampelisca* mortality > 20% in large estuaries, small estuaries, and the entire Province.

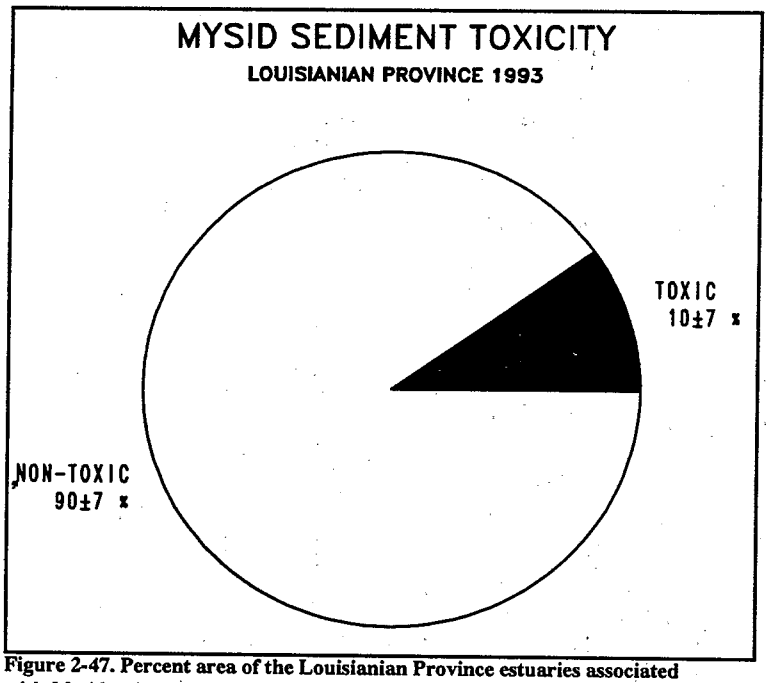


Figure 2-47. Percent area of the Louisianian Province estuaries associated with *Mysidopsis* sediment toxicity categories in 1993.

transported from California, a second organism, *Mysidopsis bahia*, was tested to see whether it provided the same results on a province-wide scale as did the amphipod. Mysids are readily culturable but do not clearly associate themselves with sediments. Mysid contact with the sediments is frequent but not continuous whereas the tube-dwelling amphipod is generally in contact with the tested sediments. About 10±7% of the sediments in the Louisianian Province was toxic to mysids resulting in mortalities >20% higher than those observed in control tests (Fig. 2-47). This figure compares favorably with the 1% observed for *Ampelisca* toxicity. The major differences between amphipod and mysid testing are shown in Figures 2-45 and 2-47 where the percentage of area demonstrating toxicity appears to be greater for mysids.

2.2.5 SEDIMENT CONTAMINANTS - ALKANES AND ISOPRENOIDS

Alkanes and isoprenoids include contaminants associated with the petroleum industry. Sediments collected throughout the Louisianian Province were analyzed for 27 individual alkanes and total alkanes. The distribution of observed concentrations for total alkanes in Louisianian Province sediments is shown in Figure 2-48 depicting concentrations ranging from 60 to 5,853 ppb. None of the sediments in the province collected in 1993 are characterized by alkane concentrations in excess of 7000 ppb. The ranges of concentrations and the percentage province-wide areas in excess of 1000 ppb for the 27 individual alkanes

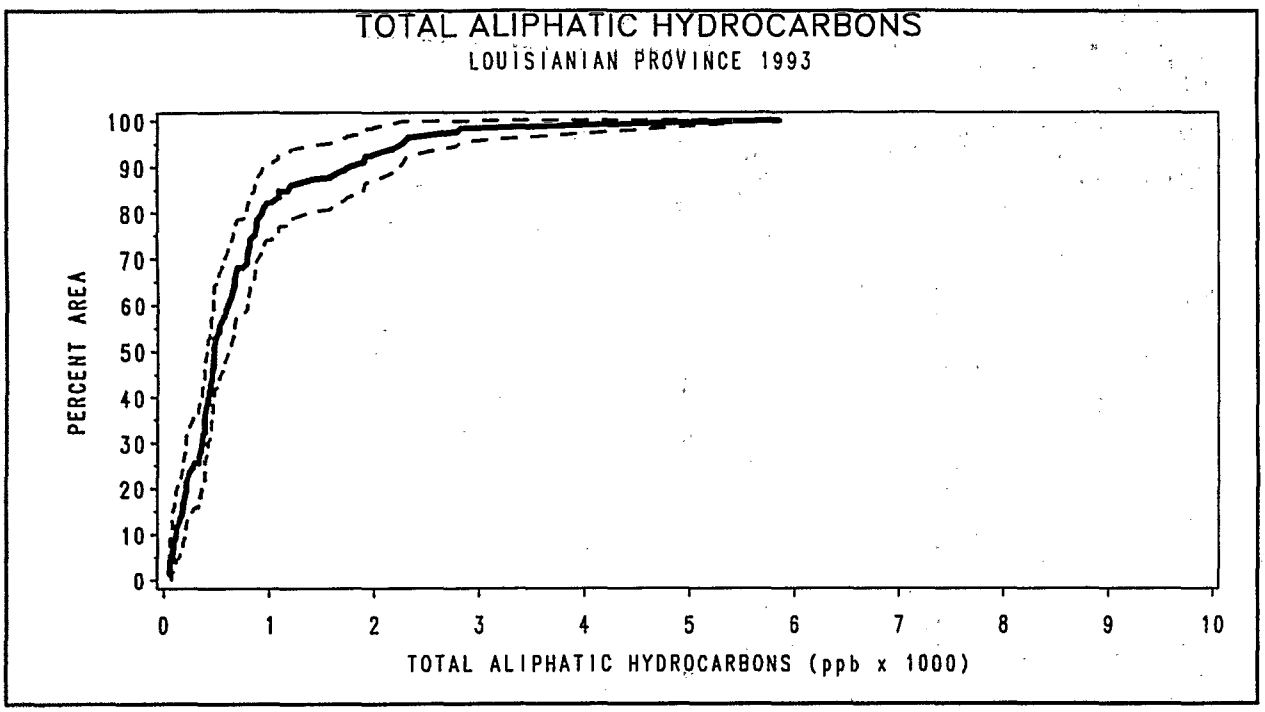


Figure 2-48. Cumulative distribution of alkanes and isoprenoids in the Louisianian Province sediments in 1993 (–) and its associated 95% confidence interval (--).

analyzed are shown in Table 2-4.

2.2.6 SEDIMENT CONTAMINANTS - POLYNUCLEAR AROMATIC HYDROCARBONS

Forty-three individual polynuclear aromatic hydrocarbons (PAHs) were analyzed from the collected Louisianian Province sediments. The distribution of the total of these 43 PAHs is shown in Fig. 2-49, ranging from 4 ppb to about 1948 ppb. None of the sampled sediments exceeded either the median (Long *et. al.* 1995) criterion of 44,792 ppb or the lower criterion of 4022 ppb.(The ranges of individual PAHs, and the criteria used are shown in Table 2-5).

For 1993 the cumulative distribution function of the relative percent of high molecular weight compounds shown in Figure 2-50 continues to show a shift in the distribution towards high-weight PAHs (see Table 2-5 for a listing of high and low molecular weights). This indicates that combustion processes are most likely the dominant sources of these compounds contributing to the observed PAHs in the Louisianian Province estuarine sediments. No differences were noted among the three estuarine classes with regard to molecular weight of PAH's. However, a slight dominance of low molecular weight PAHs was observed east of the Mississippi River while high molecular weight PAHs slightly dominated in western Gulf of Mexico estuaries. (Figures 2-51

Alkane	Range (ppb)		Percent Area > 1000 ppb
C10	0 -	68	0%
C11	0 -	77	0%
C12	1 -	88	0%
C13	0 -	77	0%
C14	1 -	72	0%
C15	2 -	259	0%
C16	1 -	56	0%
C17	3 -	345	0%
Pristane	0 -	98	0%
C18	0 -	35	0%
Phytane	0 -	49	0%
C19	0 -	77	0%
C20	0 -	92	0%
C21	1 -	389	0%
C22	1 -	61	0%
C23	1 -	168	0%
C24	1 -	98	0%
C25	2 -	261	0%
C26	1 -	125	0%
C27	3 -	646	0%
C28	1 -	182	0%
C29	3 -	1894	2%
C30	0 -	164	0%
C31	1 -	1431	2%
C32	0 -	261	0%
C33	0 -	245	0%
C34	0 -	63	0%
TOTAL	**60-**	**5853**	**0%**

Table 2-4. Alkane concentration ranges measured in the 1993 Demonstration and the percentage of province sediments exceeding 1000 ppb for individual alkanes and 7000 ppb for total alkanes.

and 2-52).

2.2.7 SEDIMENT CONTAMINANTS - POLYCHLORINATED BIPHENYLS

Louisianian Province sediments were analyzed for twenty polychlorinated biphenyl (PCB) congeners. Concentrations of total PCBs (sum of the twenty congeners) ranged from 0 to 73.3 ppb (Fig. 2-53). Given that the criterion for low-level ecological effects is 22.7 ppb for total PCBs (Long *et al* 1995), < 1% of the area in the province had concentrations that exceeded this criterion (Table 2-6).

2.2.8 SEDIMENT CONTAMINANTS - PESTICIDES

Pesticides constitute a major portion of nonpoint source runoff from agricultural fields, suburban

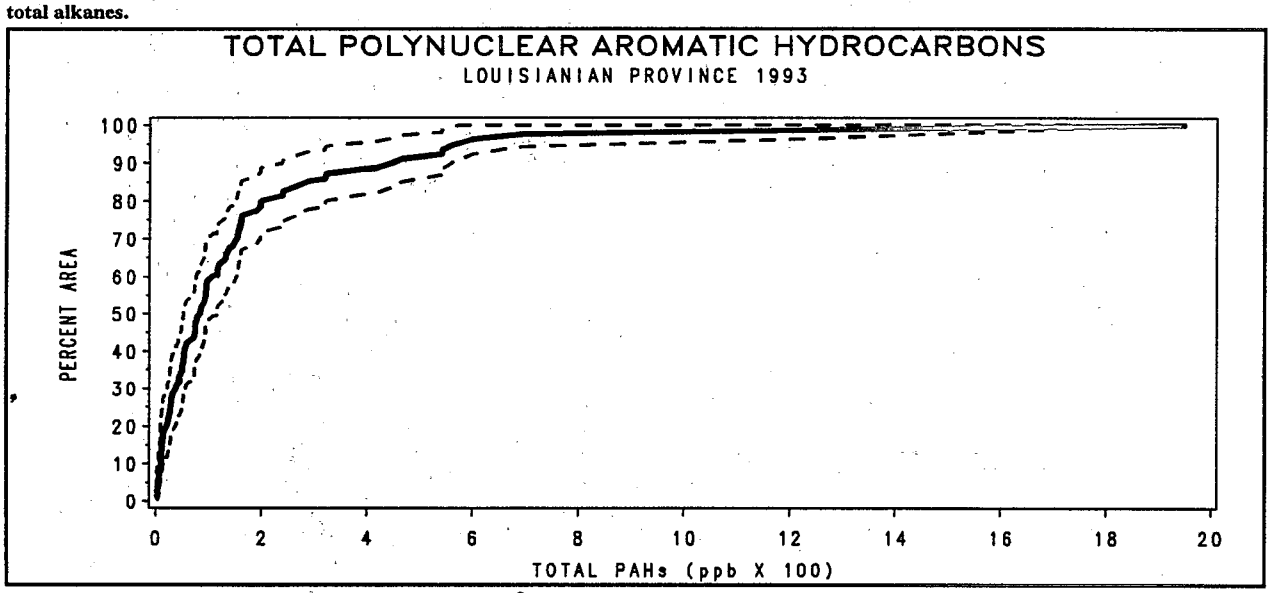


Figure 2-49. Cumulative distribution of PAH concentrations in the Louisianian Province sediments in 1993 (–) and its associated 95% confidence interval (--).

PAH	Range (ppb)	Criteria (ppb)	Percent Exceeded (10%)	(50%)
Acenaphthene(L)	0 -11	16/500	0%	0%
Acenaphthylene(L)	0 -12	44/640	0%	0%
Anthracene(H)	0 -30	85.3/1000	0%	0%
Benzo(a)anthracene(H)	0 -91	261/1600	0%	0%
Benzo(a)pyrene(H)	0 -625	430/1600	0%	0%
Benzo(b)fluoranthene(H)	0 -122	NA	U	U
Benzo(e)pyrene(H)	0 -84	430/1600	0%	0%
Benzo(g,h,i)perylene(H)	0 -94	NA	U	U
Benzo(k)fluoranthene(H)	0 -122	NA	U	U
Biphenyl(L)	0 -8	NA	U	U
Chrysene(H)	0 -88	384/2800	0%	0%
C1-chrysene(H)	0 -71	384/2800	0%	0%
C2-chrysene(H)	0 -49	384/2800	0%	0%
C3-chrysene(H)	0 -8	63.4/2800	0%	0%
C4-chrysene(H)	0 -50	63.4/2800	0%	0%
Dibenzo(a,h)anthracene(H)	0 -21	63.4/260	0%	0%
Dibenzothio(H)	0 -5	NA	U	U
C1-dibenzothio(H)	0 -14	NA	U	U
C2-dibenzothio(H)	0 -24	NA	U	U
C3-dibenzothio(H)	0 -23	NA	U	U
Fluoranthene(H)	0 -191	600/5100	0%	0%
C1-fluoranthpyrene(L)	0 -111	NA	U	U
Fluorene(L)	0 -10	19/540	0%	0%
C1-fluorene(L)	0 -7	19/540	0%	0%
C2-fluorene(L)	0 -16	19/540	0%	0%
C3-fluorene(L)	0 -23	19/540	5%	0%
Naphthalene(L)	0 -22	160/2100	0%	0%
C1-naphthalene(L)	0 -20	160/2100	0%	0%
C2-naphthalene(L)	0 -21	160/2100	0%	0%
C3-naphthalene(L)	0 -24	160/2100	0%	0%
C4-naphthalene(L)	0 -19	160/2100	0%	0%
Perylene(H)	0 -124	NA	U	U
Phenanthrene(H)	0 -87	240/1500	0%	0%
C1-phenanthrene(H)	0 -44	240/1580	0%	0%
C2-phenanthrene(H)	0 -36	240/1580	0%	0%
C3-phenanthrene(H)	0 - 43	240/1580	0%	0%
C4-phenanthrene(H)	0 -47	240/1580	0%	0%
Pyrene(H)	0 -154	665/2200	0%	0%
(i)1,2,3-c,d-pyrene(H)	0 - 97	NA	U	U
1-methylnaphthalene(L)	0 -9	NA	U	U
2-methylnaphthalene(L)	0 -11	70/670	0%	0%
2,3,5 Trimethylnapthalene(L)	0 -6	NA	U	U
2,6 Dimethylnapthalene(L)	0 -8	NA	U	U
1-methylphenanthrene(H)	0 -8	NA	U	U
High Molecular Wt. PAHs	1-1777	1700/9600	1%	0%
Low Molecular Wt. PAHs	2-173	552/3160	0%	0%
Total PAHs	4-1948	4022/44792	0%	0%

Table 2.5 Ranges of PAH concentrations found in the 1993 Louisianian Province Demonstration, criteria used for comparison from Long and Morgan (1990) [x/y where x = concentration where biological effects occurred 10% of the time and y = median concentration for effects to occur], and the percent of sediments exceeding these criteria. (NA = None Available; U = Unknown)

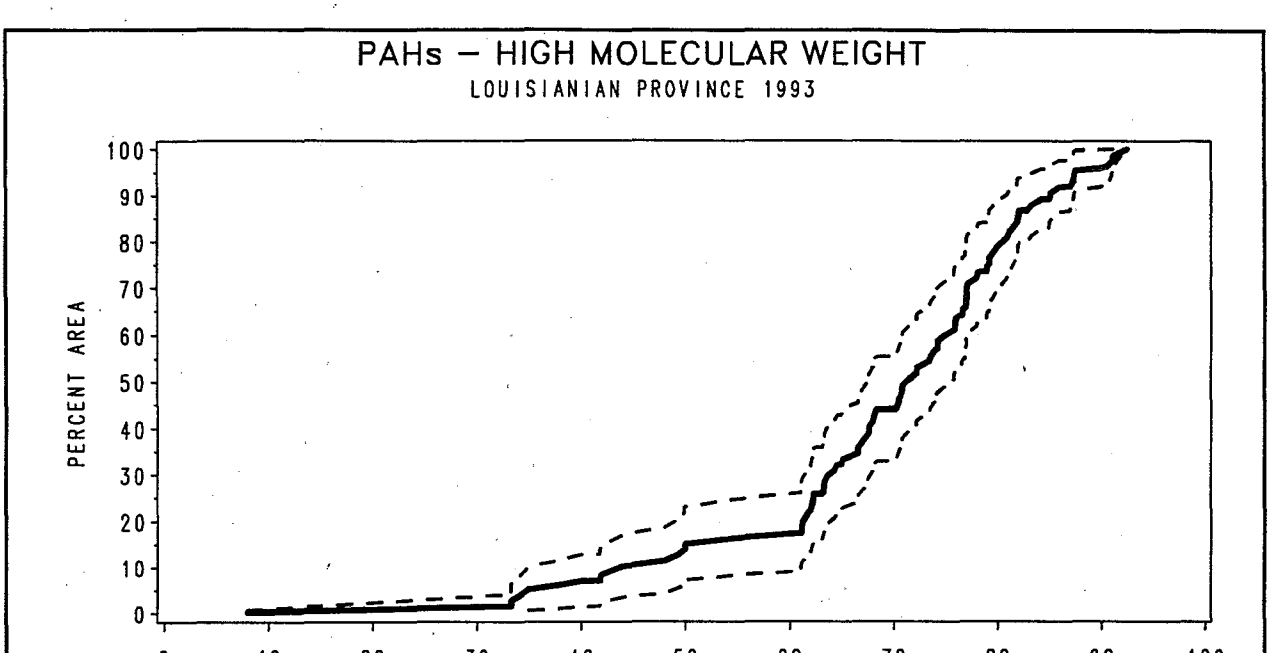


Figure 2-50. Cumulative distribution of high molecular weight PAH concentrations in the Louisianian Province sediments in 1993 (–) and its associated 95% confidence interval (--).

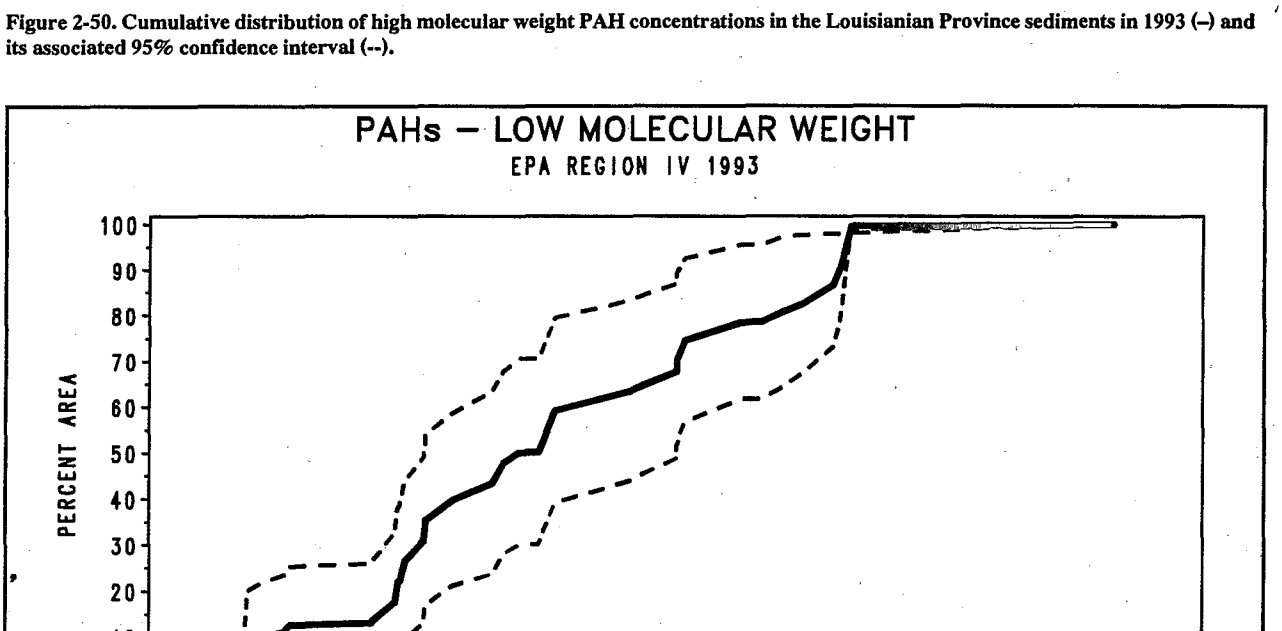


Figure 2-51. Cumulative distribution of low molecular weight PAH concentrations in the Louisianian Province sediments in 1993 east of the Mississippi River (–) and its associated 95% confidence interval (--).

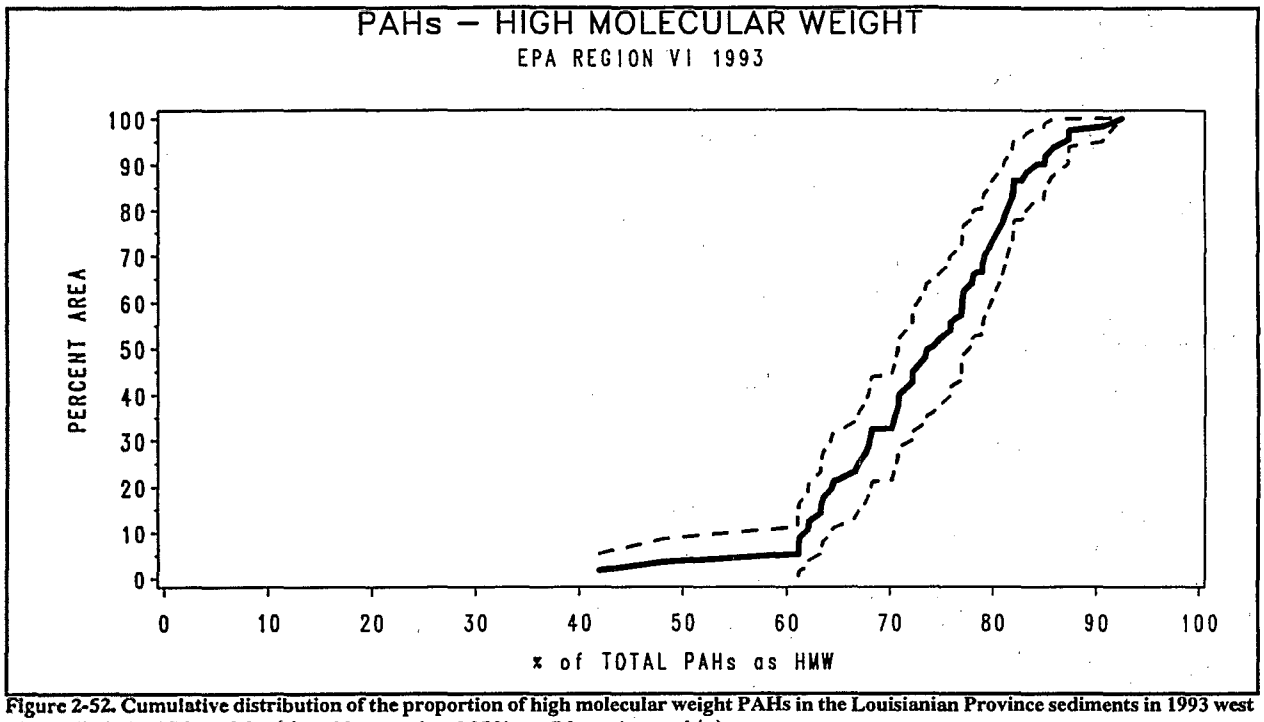


Figure 2-52. Cumulative distribution of the proportion of high molecular weight PAHs in the Louisianian Province sediments in 1993 west of the Mississippi River delta (–) and its associated 95% confidence interval (--).

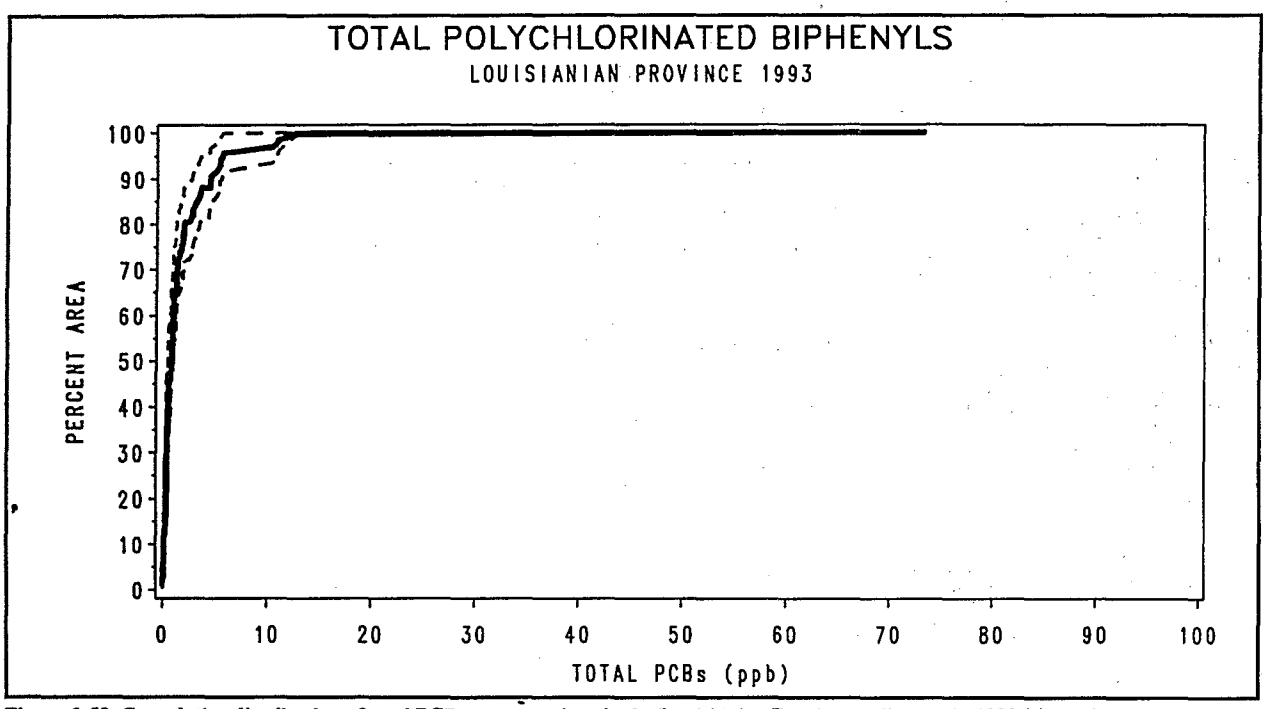


Figure 2-53. Cumulative distribution of total PCB concentrations in the Louisianian Province sediments in 1993 (–) and its associated 95% confidence interval (--).

PCB # (Congener)	Range (ppb)
8 (CL2)	0 - 1.0
18 (CL3)	0 - 0.5
28 (CL3)	0 - 0.9
44 (CL4)	0 - 0.3
52 (CL4)	0 - 1.0
66 (CL4)	0 - 0.6
101 (CL5)	0 - 1.2
105 (CL5)	0 - 0.3
110/77 (CL5/4)	0 - 2.0
118/108/149 (CL 5/5/6)	0 - 1.1
126 (CL5)	0 - 0.9
128 (CL6)	0 - 0.4
138 (CL6)	0 - 1.3
153 (CL6)	0 - 1.5
170 (CL7)	0 - 72.4
180 (CL7)	0 - 0.6
187/182/159 (CL 7/7/6)	0 - 0.2
195 (CL8)	0 - 0.1
206 (CL9)	0 - 0.1
209 (CL10)	0 - 0.7
TOTAL PCBs	0 - 73.3

Table 2.6 Ranges of polycyclic chlorinated biphenyl concentrations determined from Louisianian Province sediments.

Pesticide	Range (ppb)	Criteria (ppb)	Percent Exceeded (10%)	Percent Exceeded (50%)
2,4 DDD	0 - 0.31	2.0/20	0%	0%
4,4 DDD	0 - 1.49	2.0/20	0%	0%
2,4 DDE	0 - 1.01	2.2/22	0%	0%
4,4 DDE	0 - 2.43	2.2/22	0%	0%
2,4 DDT	0 - 0.51	1.0/7	0%	0%
4,4 DDT	0 - 0.92	1.0/7	0%	0%
Total DDTs	0 - 3.90	22.7/180	0%	0%
Aldrin	0 - 0.31	NA	U	U
Alpha-BHC	0 - 0.30	NA	U	U
beta-BHC	0 - 0.41	NA	U	U
delta-BHC	0 - 0.22	NA	U	U
alpha-Chlordane	0 - 0.27	.5/6	0%	0%
gamma-Chlordane	0 - 0.37	.5/6	0%	0%
Dieldrin	0 - 0.68	.02/8	57%	0%
Endosulfan	0 - 0.46	NA	U	U
Endrin	0 - 0.19	.02/45	18%	0%
Hexachlorobenzene	0 - 22.60	NA	U	U
Heptachlor	0 - 0.17	NA	U	U
Heptachlor Epoxide	0 - 11.83	NA	U	U
Mirex	0 - 2.58	NA	U	U
cis-Nonachlor	0 - 0.16	NA	U	U
trans-Nonachlor	0 - 0.23	NA	U	U
Oxychlordane	0 - 0.19	NA	U	U
Lindane	0 - 0.59	NA	U	U
Chlorpyritos	0 - 0.54	NA	U	U
Docotol	0 - 0.04	NA	U	U
Total BHCs	0- 4.13	NA	U	U

Table 2.7. Ranges of pesticide concentrations found in the 1993 Louisianian Province Demonstration, criteria used for comparison from Long and Morgan (1990) [x/y where x=concentrations where biological effects occurred 10% of the time and y=median concentration for effects to occur], and the percent of sediments exceeding these criteria. (NA = None Available; U = Unknown)

lawns, and golf courses. Twenty-five chlorinated insecticides, including DDT and its derivatives, and one fungicide were analyzed from Louisianian Province sediments. No pesticides have accepted sediment criteria; therefore, we used the few criteria available from Long and Morgan (1990) for DDT and its derivatives, chlordane, endrin, and dieldrin. The criterion for 4,4'DDE is from Long *et. al.* 1995. The ranges of observed concentrations of all pesticides examined are shown in Table 2-7.

No DDT or chlordane concentrations above the criteria were found in the sediments of the Louisianian Province.

Endrin concentrations did not exceed its median criterion (45 ppb) in any of the sediments examined from the Louisianian Province; however, 18% of sediment contained endrin at > 0.02 ppb (Fig. 2-54).

Dieldrin concentration did not exceed its median criterion of 8 ppb in any sediments collected from the Louisianian Province; however, 57% of sediments had dieldrin concentrations > 0.02 ppb, (Fig. 2-55) the 10% effects-level listed by Long & Morgan (1990).

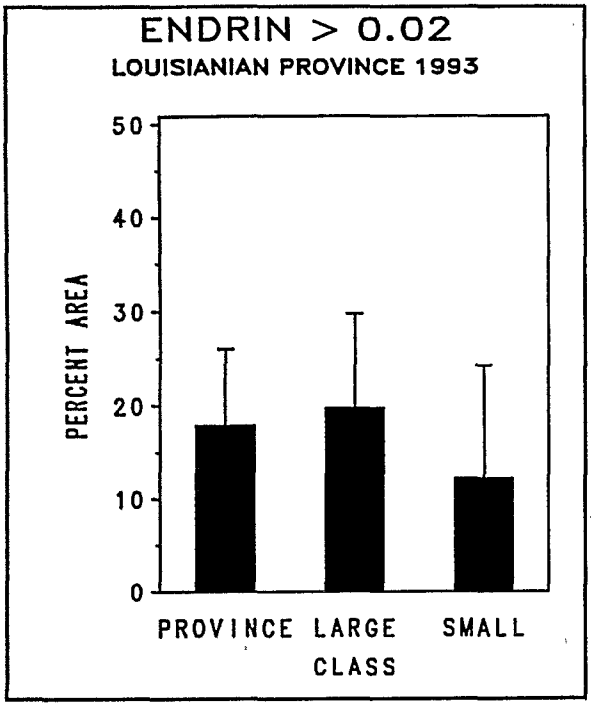


Figure 2-54. Percent of area having sediments with Endrin > 0.02 ppb for large estuaries, small estuaries, and the entire Province.

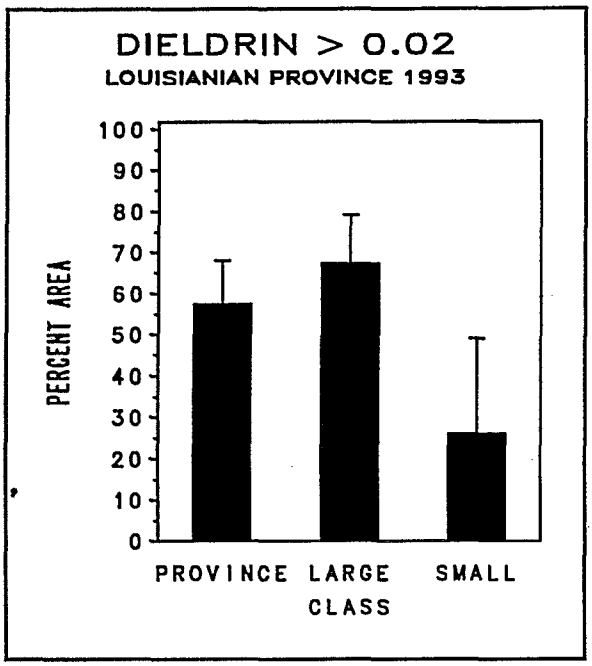


Figure 2-55. Percent of area having sediments with Dieldrin > 0.02 ppb for large estuaries, small estuaries, and the entire Province.

Metal	Range(ppm)	Criteria (ppm)	Percent Exceeded (10%)	(50%)
Aluminum	770 -10400	NA	U	U
Antimony	0 - 1.3	2/25	0%	0%
Arsenic	0.3 - 30.4	33/85	33%	0%
Cadmium	0 - 1.5	1.2/9	1%	0%
Chromium	0 -104.4	51/370	9%	0%
Copper	0 - 31.3	24/270	0%	0%
Iron	330 -74600	NA	U	U
Lead	1 - 35	46.7/218	0%	0
Manganese	0 - 1710	NA	U	U
Mercury	0 - 0.2	.15/.71	3%	0%
Nickel	0 - 36.7	20.9/51.6	35%	0%
Selenium	0 - 1.8	NA	U	U
Silver	0 - 0.3	3/3.7	0%	0%
Tin	0 - 3.9	NA	U	U
Zinc	5.2 - 200	150/410	4%	0%

Table 2-8. Ranges of heavy metal concentrations found in the 1993 Louisianian Province Demonstration, criteria used for comparison from Long and Morgan (1990) [x/y where x = concentration where biological effects occurred 10% of the time and y = median concentration for effects to occur], and the percent of sediments exceeding these criteria. NA = None Available; U = Unknown)

2.2.9 SEDIMENT CONTAMINANTS - HEAVY METALS

Fifteen heavy metals were analyzed for the sediments collected in the 1993 Louisianian Province Demonstration. These metals were examined from two perspectives: (1) Criteria-based and (2) Anthropogenic enrichment. Criteria-based analyses were conducted similarly to those for other contaminants where a criterion of degradation was selected for each metal and distributional analysis showed the proportion of the sediments exceeding that criterion value. Anthropogenic enrichment was determined using a reduced data set and regressing metal concentrations against aluminum concentrations. The data set reduction required the removal of clearly elevated concentrations (i.e., metal concentrations > 10% Long and Morgan Values). Once the regression is completed, the

complete data set is compared to the upper 95% confidence interval of the regression. All sites with concentrations exceeding the upper 95% confidence interval are considered to be anthropogenically enriched with regard to metals.

2.2.10. CRITERIA COMPARISONS

Table 2-8 shows the ranges of heavy metals concentrations found during the 1993 Louisianian Province Demonstration and their criteria values for comparison. Only arsenic, chromium, nickel, and to a lesser extent, cadmium, mercury, and zinc exceed the selected criteria values (Table 2-8). Using the lower criteria (i.e., concentrations resulting in effects 10% of the time), 39±11% of sediments in the Louisianian Province have at least one metal concentration in excess of these values (Fig. 56) whereas only 1±4% of the sediments has at least one metal which exceeds the higher criteria. Over 29% of the sediments have two or more metals exceeding the lower criteria. The high percentage of sediments with metals that exceed criteria is due, in part, to the change in ERL criteria for arsenic from 33 to 8.2 ppm and for nickel from 30 to 20.9 ppm. This change in criteria resulted in an increase in the percent of sediments that have values of arsenic and nickel that are greater than criteria. In 1992, 0% of the sediments had high arsenic values whereas in 1993, 32% of the sediment in the Province had arsenic values greater than ERL criteria. Nickel changed from exceeding criteria in 10% of the sediments in 1992 to exceeding criteria in 34% of the sediments in 1993. The range of values between the two years, however, did not change (maximum value for arsenic was 28.8 ppm in 1992 and 30.4 ppm in 1993; maximum value for nickel was 36.9 in 1992 and 36.2 in 1993).

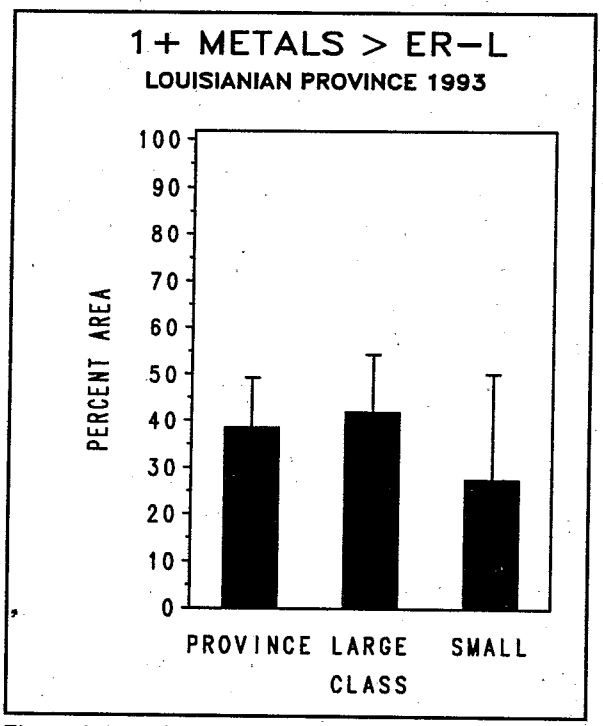


Figure 2-56. Percent area of estuaries with at least one metal concentration greater than Long *et al.*'s ERL (concentrations resulting in effects 10% of the tine) value in large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

These high metal concentrations are found primarily in large estuary classes (42±12%) with 27±23% in small estuaries (Fig.56).

2.2.10.1 ANTHROPOGENIC ENRICHMENT

Aluminum concentrations vary greatly (770-10400 ppm) in the Louisianian Province. As aluminum content in sediments is primarily derived from the natural crust of the earth, this wide variation generally is accompanied by wide variations in the portion of other metals observed that are attributable to the earth's crust. Therefore, the observed metal concentrations should be adjusted for a reference metal (i.e., aluminum). This approach has been used numerous times in estuarine environments (Klinkhammer and Bender 1981, Trefry *et al.*

1985, Windom *et al.* 1989, Schropp *et al.* 1990). Simple log-log regressions were completed using aluminum and each of the other observed metals. All regressions were significant (< 0.05); thus, aluminum was used as the adjustment reference metal.

Sampling sites that were within the 1991, 1992 and 1993 Louisianian Province Demonstration data sets that were determined to be representative of natural, unenriched areas were selected to develop the regressions (Summers *et al* 1995). The results of these regressions are shown in Table 2-9. The metal-specific regression slope and its associated 95% confidence intervals were then compared with the complete data set and all locations falling above the 95% confidence interval represented sites that were anthropogenically enriched. The results of these regression analyses for all metals revealed some enrichment of all metals except silver, although the technique would be expected to show 1-2% enrichment as an artifact of the technique. Even with this slight bias, enrichment of Louisianian Province sediments is evident for arsenic, cadmium, chromium, mercury, and zinc (3 to 17% of sediments) (Fig. 2-57).

By comparison, the two methods yielded very similar results with 61±11% of the sediments meeting the criteria levels and 71±10% of the sediments being "unenriched" (Fig. 2-58). While the overall picture is the same, inspection of Fig.2-57 shows some marked differences. While arsenic and nickel levels exceed criteria values for 32-34% of sediments, aluminum-adjusted concentrations show much reduced enrichment (1 to 17%). This is most likely the result of the change in criteria values discussed in the previous section. Conversely, copper and lead never exceed their criteria but, based on regressions with aluminum are enriched in 1-3% of Louisianian Province sediments.

Metal (y)	Transform	N	R^2	Slope	Intercept
Arsenic-1	$\sqrt{x}$	340	0.70	2.562	-0.139
Arsenic-2	ln y	496	0.73	0.213	0.906
Cadmium	$\sqrt{y}$	485	0.41	0.041	0.183
Chromium	none	444	0.84	8.148	4.909
Copper	wtd by 1/x	483	.0.89	2.155	0.290
Lead	$\sqrt{y}$, $\sqrt{x}$	476	0.91	1.443	0.762
Mercury	$\sqrt{y}$	448	0.50	0.017	0.124
Nickel-1	none	319	0.84	2.864	0.889
Nickel-2	$\sqrt{y}$	497	0.87	0.549	1.291
Silver	none	491	0.43	0.016	0.041
Zinc	$\sqrt{y}$, $\sqrt{x}$	480	0.88	3.316	0.711

Table 2-9. Transformations and results of regressions that were applied to 1991-1993 aluminum vs. metals data. Correlations between all metals and Al were significant (p<0.001). Nickel-1 and Arsenic-1 were regressed using only values less than ERL guidelines. Nickel-2 and Arsenic-2 were regressed using all of the data except statistical outliers. (reprinted with permission from Summers *et al* 1995).

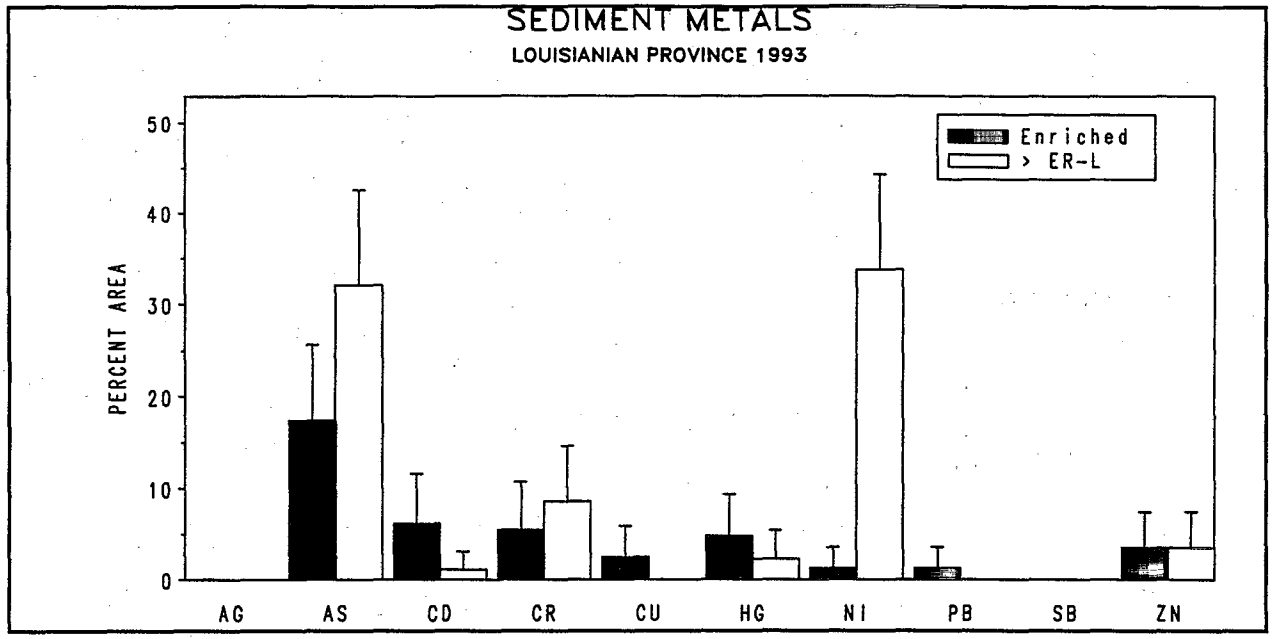


Figure 2-57. Percent area of estuaries in Louisianian Province with sediment metal concentrations > 10% Long-Morgan criteria (concentration resulting in effects 10% of the time) or greater than expected based on aluminum cconcentrations, with 95% confidence interval.

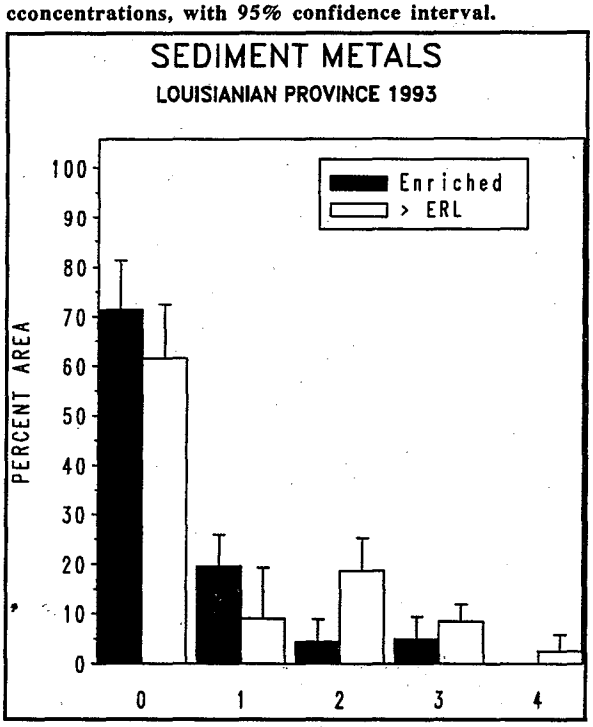


Figure 2-58. Percent area of estuaries in Louisianian Province with one or more sediment heavy metal concentrations > 10% Long-Morgan sediment criteria or greater than expected based on aluminum concentrations, with 95% confidence interval.

2.2.11 SEDIMENT CONTAMINANTS - BUTYLTINS

Tributyltin (TBT), a compound found in anti-fouling paints until recently, was an effective and widespread means of protecting recreational and commercial craft from fouling organisms in seawater. TBT is considered highly toxic and is a serious environmental concern. TBT has been shown to affect shell generation in oysters (Weis and Perlmutter 1987, Weis 1988) and alter the reproductive dynamics of whelks (Weis and Perlmutter 1987). Although TBT is not believed to be a persistent chemical, having a half-life of 7 to 12 days, its continual release through leaching remains a persistent environmental problem. Determination of tributyltin was made for all sediments collected in the 1993 Louisianian Province Demonstration with concentrations expressed as ng (Sn)/g dwt. Only 9±6% of the sediments analyzed showed no traces of TBT. Ninety-one percent (±6%) of the

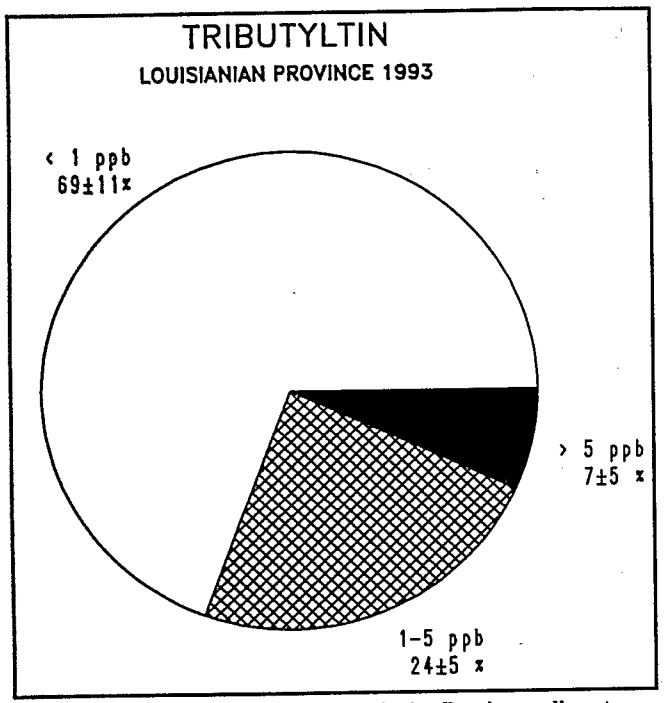


Figure 2-59. Percent of area of the Louisianian Province sediment associated with tributyltin concentration categories in 1993.

sediments had concentrations of TBT > 0, with 7±5% having concentrations > 5 ppb (Fig. 2-59). According to Laughlin *et al.* (1984), long-term tests of tributyltin compounds on fish and invertebrates suggest that the maximum acceptable concentration for TBT would be < 1 ppb. Using 1 ppb TBT as an indicator of potential ecological effects results in all sampling classes being represented with 21% of sediments in small estuaries, and 34% of sediments in large estuaries having measurable TBT (Fig. 2-60).

2.3 HABITAT INDICATORS

Habitat indicators describe the natural physical and chemical conditions of the locations sampled in the 1993 Louisianian Province Demonstration. These parameters are discussed below.

2.3.1 WATER DEPTH

The Louisianian Province is comprised primarily of large and small shallow estuaries with water depths rarely exceeding 3 to 4 m except in dredged channels or the Mississippi River. The distribution of water depth observed in the Louisianian Province in 1993 is shown in Fig. 2-61. The proportions of the estuarine classes that have water depths of less than three meters are shown in Fig. 2-62, with large and small estuaries showing significant expanses of shallow water (58±13% of large estuaries and 88±20% of small estuaries).

2.3.2 WATER TEMPERATURE

Water temperature remained relatively constant, regardless of location, over the six-week sampling period of the Louisianian Province

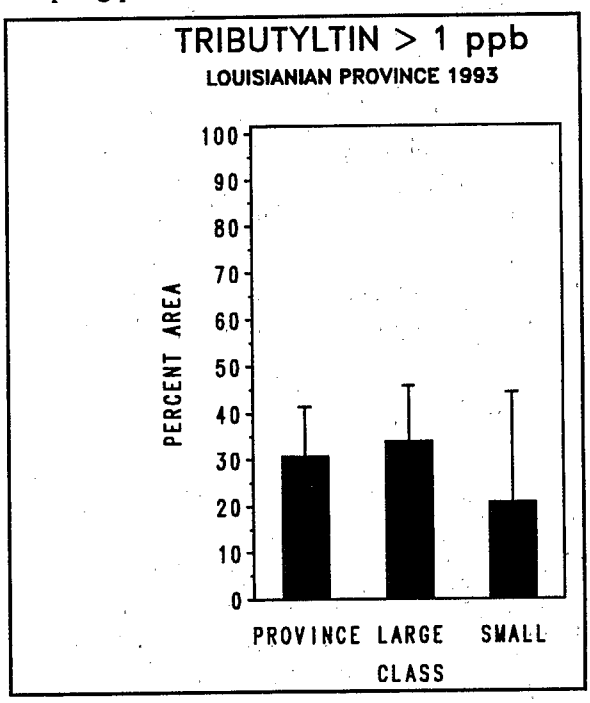


Figure 2-60. Percent of area having sediments with tributyltin > 5 ppb for large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

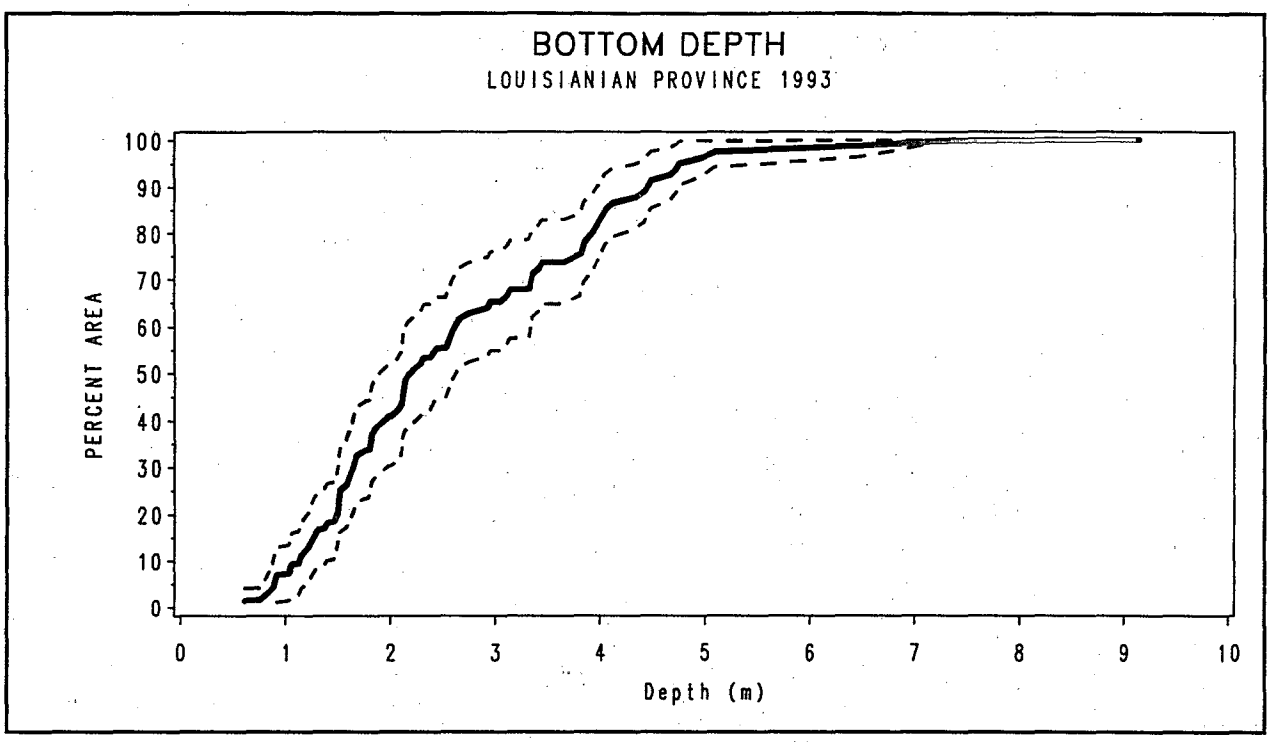


Figure 2-61. Cumulative distribution of water depth in the Louisianian Province in 1993 (–) and its associated 95% confidence interval (--).

Demonstration. The total range of bottom water temperature observed in July and August spanned only ten degrees Celsius (Fig. 2-63), from 24° C to 34° C. Estuarine biota and habitats in the Louisianian Province are exposed to water temperature above 24° C continuously throughout the index sampling period (July and August).

2.3.3 SALINITY

Salinity varied widely among sampling locations. Popular opinion would suggest that salinities in Gulf of Mexico estuaries in late summer would be predominately polyhaline (i.e., > 18 ppt). In 1993 51±11% of the Louisianian Province was made up of polyhaline waters. Salinity ranged from 0 to 38 ppt throughout the province (Fig. 2-64). Continuous salinity measurements did not show any changes in the observed salinity range

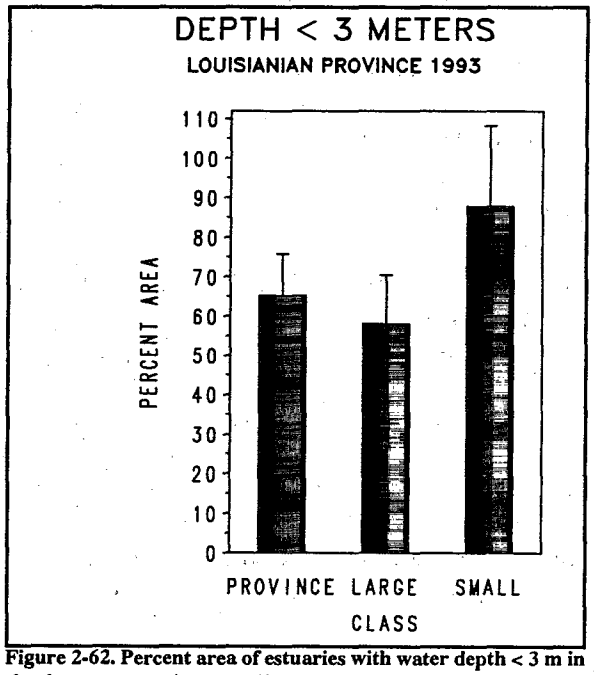


Figure 2-62. Percent area of estuaries with water depth < 3 m in the large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

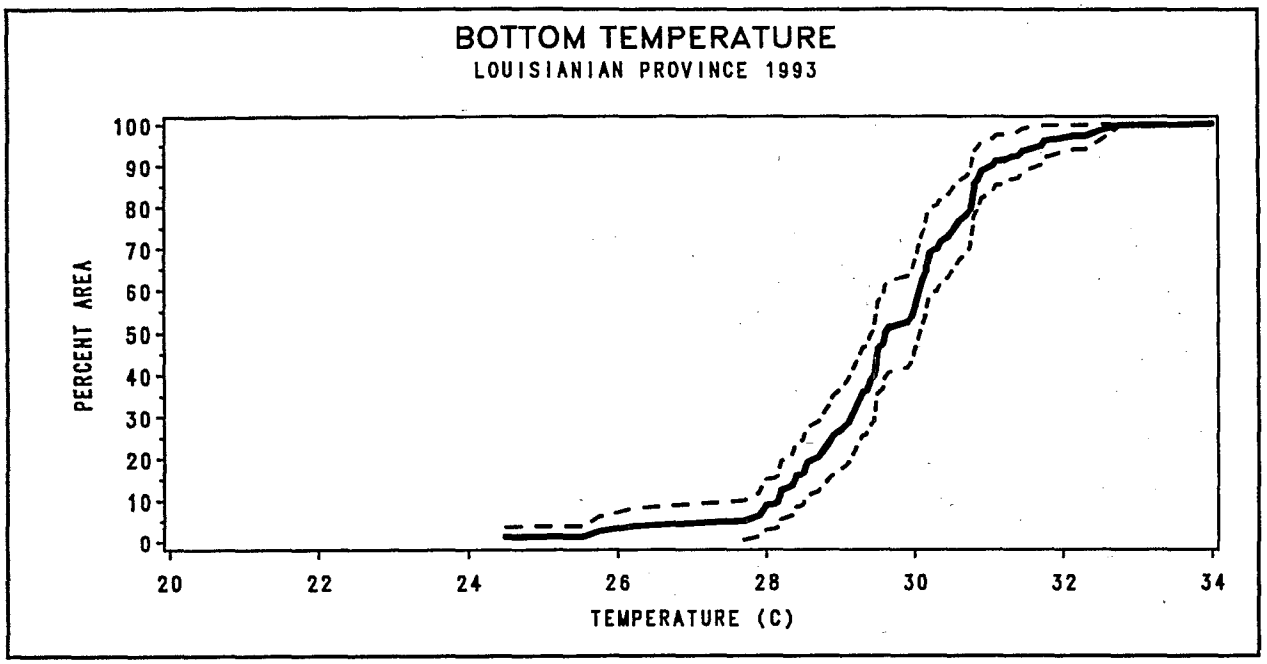


Figure 2-63. Cumulative distribution of water temperature in the Louisianian Province in 1993 (–) and its associated 95% confidence interval (--).

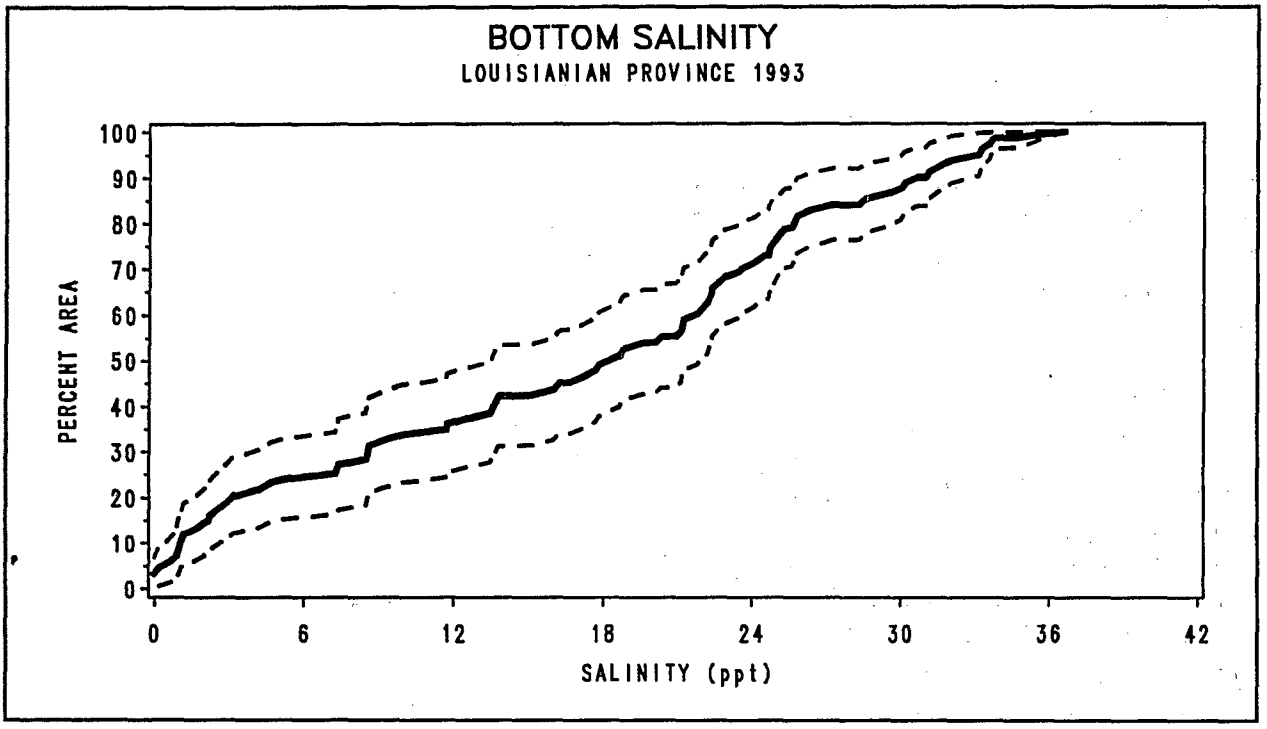


Figure 2-64. Cumulative distribution of bottom salinity in the Louisianian Province in 1993 (–) and its associated 95% confidence interval (--).

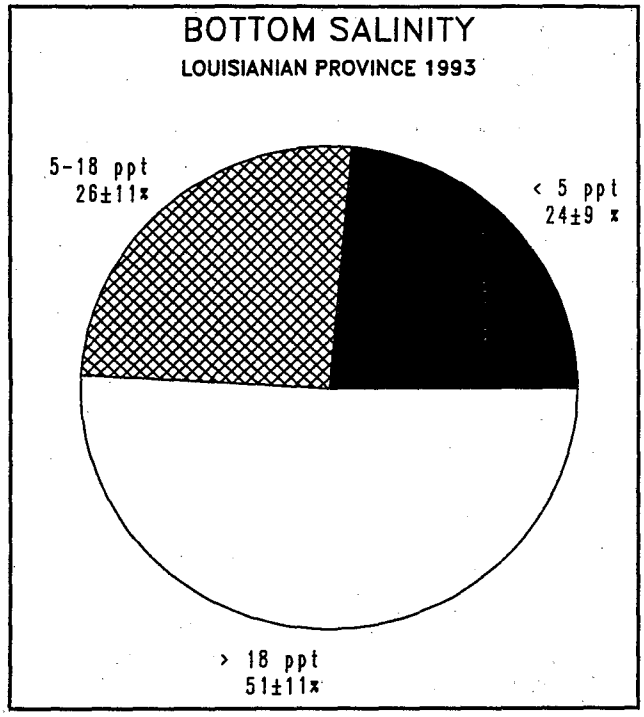


Figure 2-65. Percent area of estuaries with oligohaline, mesohaline, and polyhaline bottom waters in the Louisianian Province in 1993.

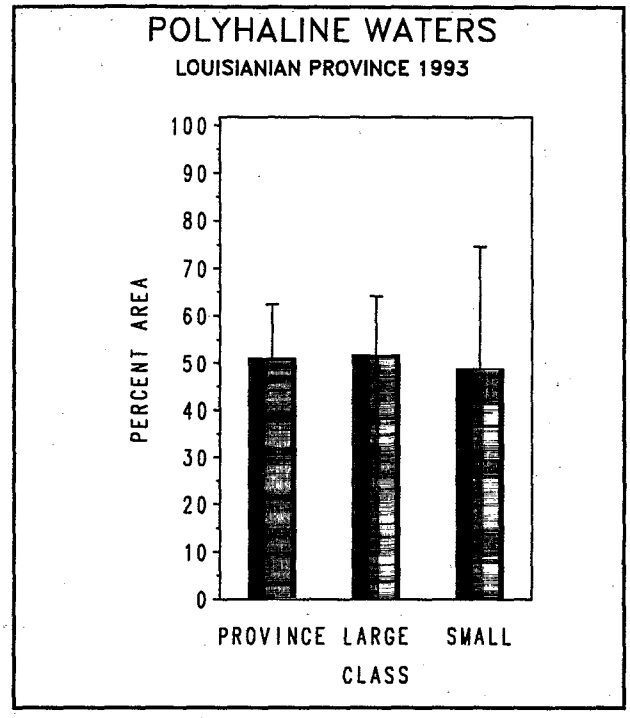


Figure 2-66. Percent area of estuaries with polyhaline salinities in large estuaries, small estuaries, and the entire Province, with 95% confidence interval.

or distribution. Oligohaline waters (0 to 5 ppt) comprised 24±9% of the province estuarine waters, mesohaline waters (5 to 18 ppt) contributed 26±11%, while polyhaline waters made up the majority of the resource at 51±11% (Fig. 2-65). As expected, the large estuarine waters were primarily polyhaline in 1993 (Fig. 2-66). Large and small estuaries are about 27 to 11% oligohaline (Fig. 2-67).

2.3.4 PH

Estuaries are primarily neutral bodies of water with changes in pH often quickly modified by the ions associated with salinity. However, as stated above, about one-third of the estuarine waters of the Louisianian Province were tidal fresh to brackish in 1993. Bottom pHs ranged

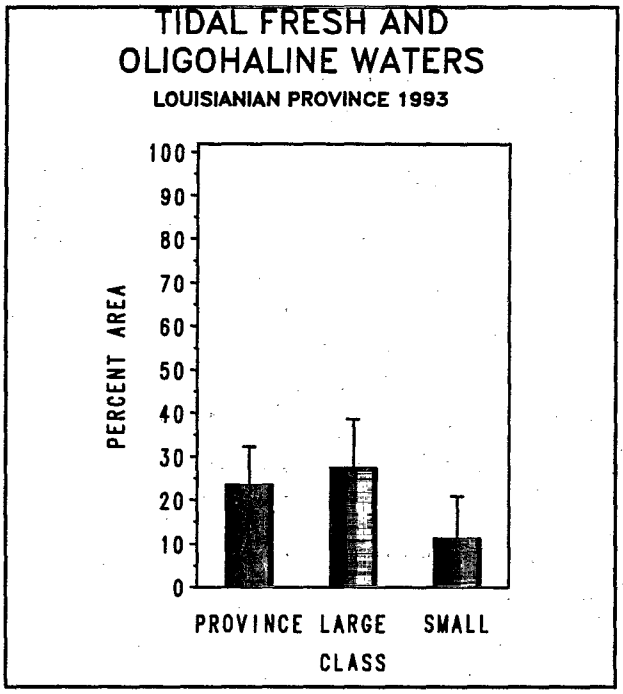
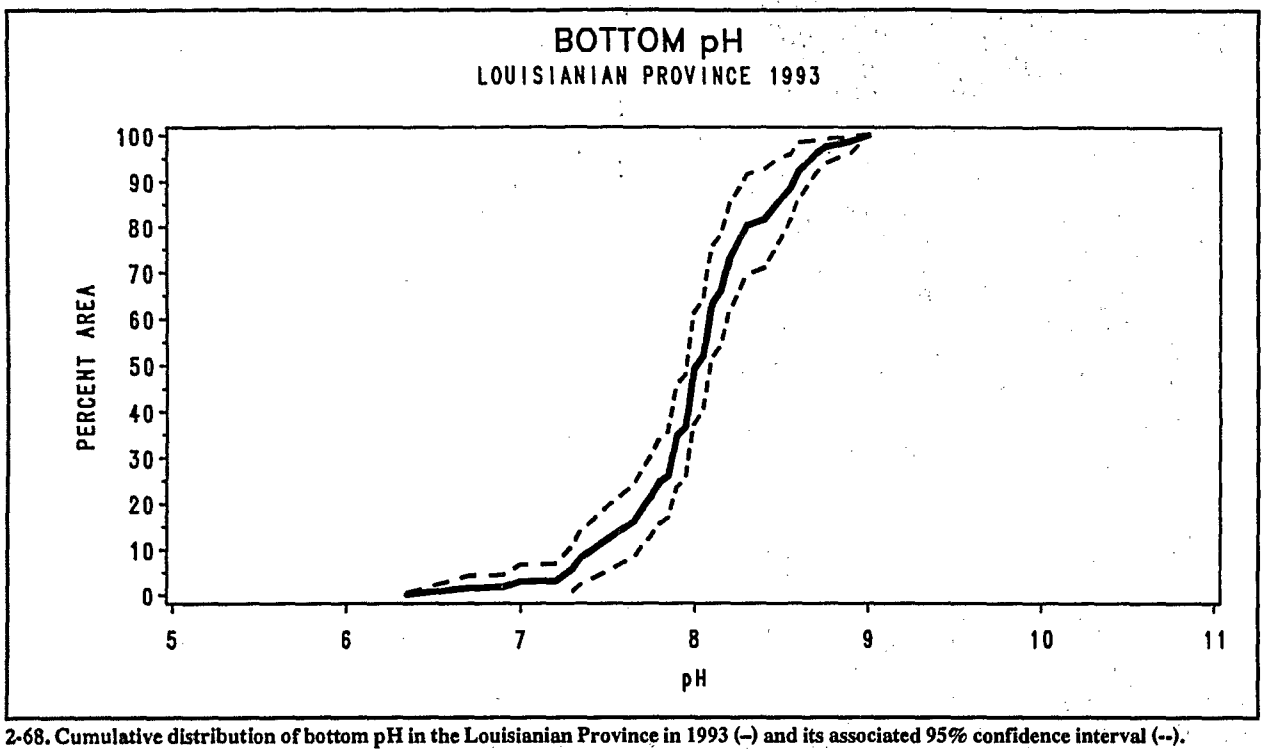


Figure 2-67. Percent area of estuaries with oligohaline bottom waters in large estuaries, small estuaries, and the entire Province, with 95% confidence interval.



2-68. Cumulative distribution of bottom pH in the Louisianian Province in 1993 (–) and its associated 95% confidence interval (--).

from 6.4 to 9.0 (Fig. 2-68) during the sampling period. In 1993 2±3% of large estuaries and 2±3% of small estuaries had pH values < 7.0.

2.3.5 STRATIFICATION

Previous studies have shown that the probability of finding low dissolved oxygen concentrations is greater in areas where there is density stratification of the water column. This occurs because stratification reduces exchange between oxygen-poor bottom and oxygen-rich surface waters. Results from the 1993 Louisianian Province Demonstration show that surface-to-bottom salinity differences range from 0.5 to 25 ppt often over only 2 to 3 m of water column (Fig. 2-69). Normally, density stratification or delta sigma-T is calculated using both salinity and temperature differences. However, because water temperature is relatively constant from surface to bottom throughout the province, stratification has been approximated based solely on salinity differences. Significant stratification (i.e., salinity differences of > 6 ppt) occurs in only about 19±8% of the estuarine waters in the province and is primarily seen in large estuaries.

2.3.6 PERCENT SILT-CLAY CONTENT

The composition of bottom sediments in terms of grain size or percentage of silts and clays can be an important determinant of the types of estuarine organisms utilizing the bottom. The Louisianian Province is comprised of 35±11% mud (> 80% silts and clays), 44±11% intermediate muddy-sand (20-80% silts and clays), and 21±9% sand (< 20% silts and clays) (Fig. 2-70). Large estuaries are comprised of

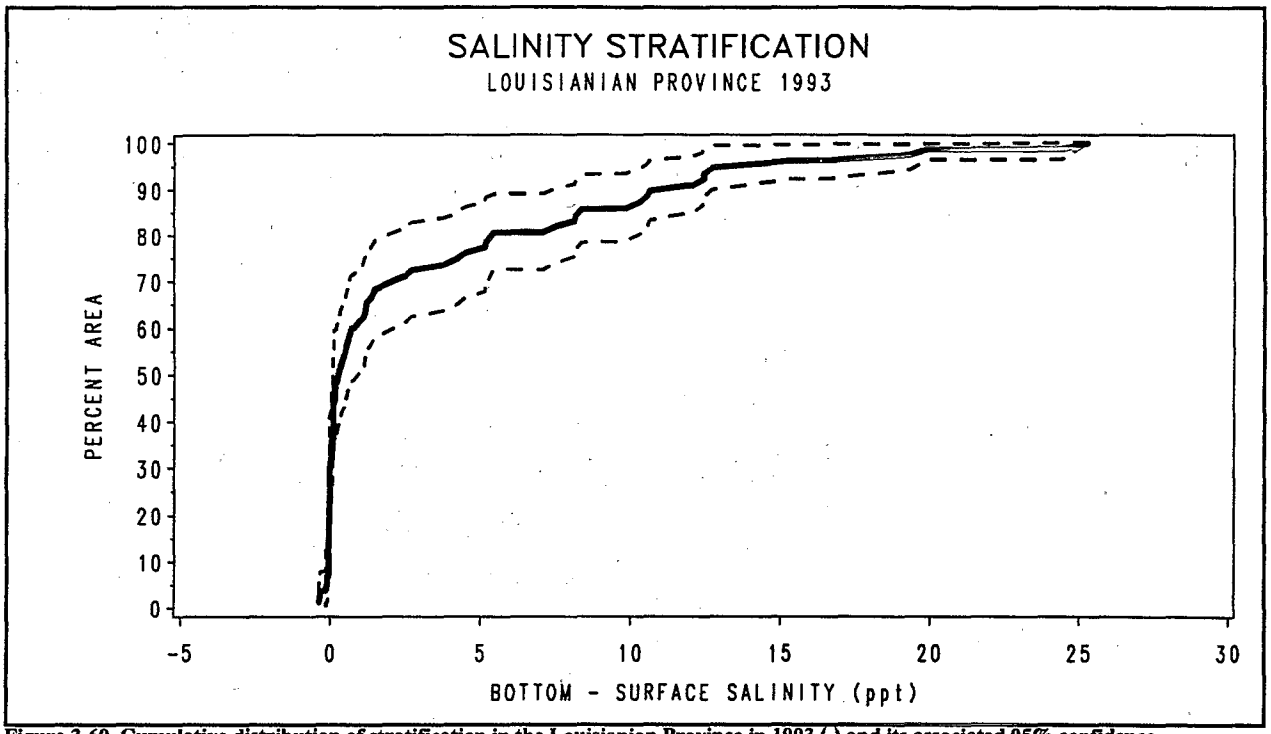


Figure 2-69. Cumulative distribution of stratification in the Louisianian Province in 1993 (-) and its associated 95% confidence interval (--).

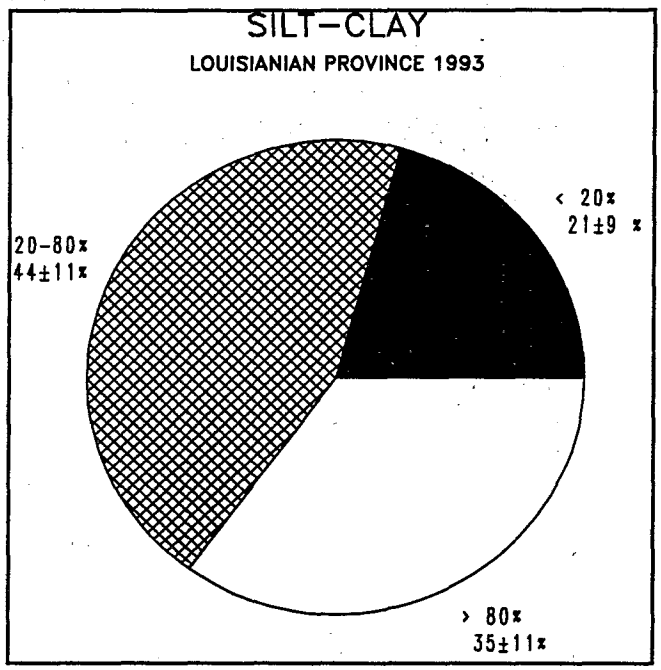


Figure 2-70. Percent area of estuaries in the Louisianian Province associated with percent silt-clay categories in 1993.

mainly intermediate muddy-sand (47±12%) while small estuaries were mainly mud (38±25%).

2.3.7 PERCENT TOTAL ORGANIC CARBON

Another important physico-chemical characteristic of estuarine sediments is the proportion of organic carbon in the sediments. High levels (> 2%) of total organic carbon (TOC) suggest possible organic enrichment, whether naturally through detrital accumulation or anthropogenically through point source discharges. Based on the results of the 1993 Louisianian Province Demonstration, sediments in the province range from nearly pure sand (no organic carbon) to highly enriched sediments approaching 14% TOC (Fig. 2-71). Low to normal organic carbon content (0-1%) was found in 49%±11% of province sediments,

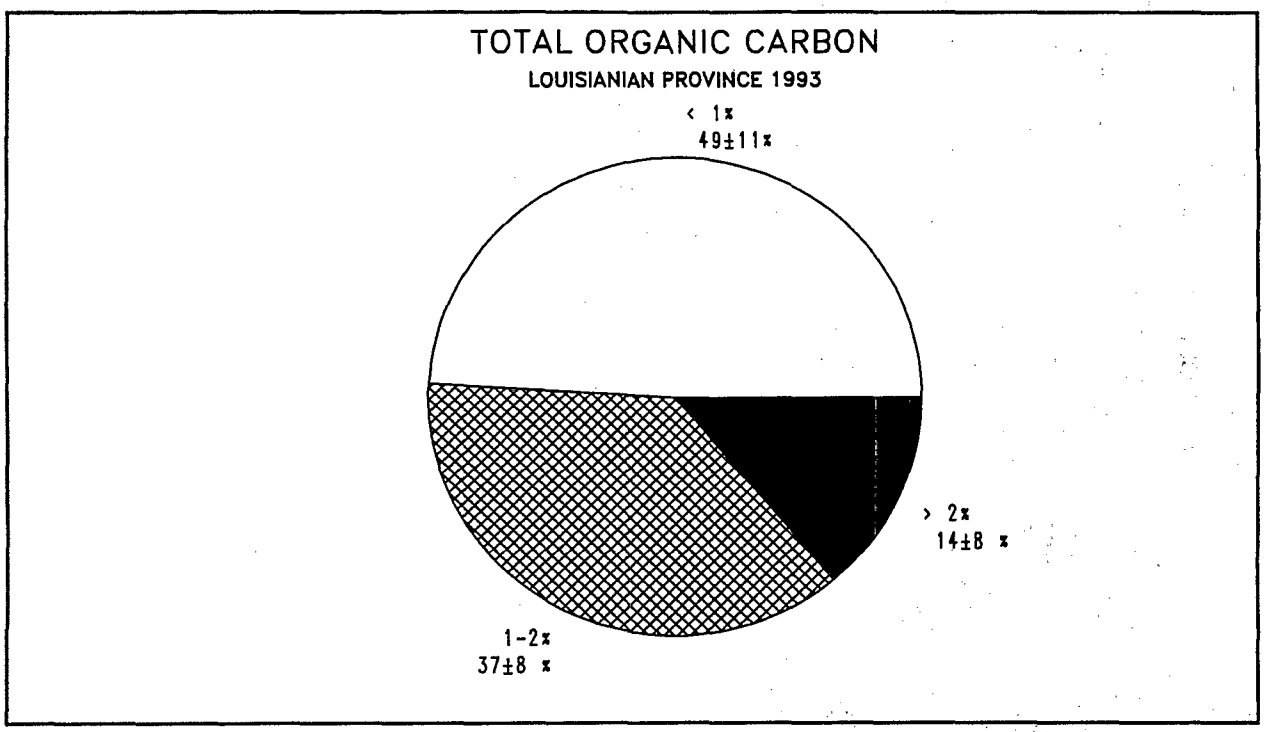


Figure 2-71. Cumulative distribution of percent organic carbon in sediments in the Louisianian Province in 1993 (–) and its associated 95% confidence interval (--).

37%±8% of the province was slightly enriched, while 14%±8% was enriched to the extent of producing a sediment that was > 2% TOC (Fig. 2-71). About 14 to 17% of the sediments from large and small estuarine systems have organic carbon content > 2% (Fig.2-72).

2.3.8 ACID VOLATILE SULFIDES

Acid volatile sulfides (AVS) measure the amorphous or moderately crystalline monosulfides in sediments that are important in controlling the bioavailability of metals under anoxic conditions (DiToro *et al.* 1991). AVS in the Louisianian Province ranged from 0 to 20 micromoles AVS/ g dwt sediment (Fig. 2-73).

2.4 CONFIDENCE INTERVALS FOR PROVINCE AND CLASS-LEVEL ESTIMATES

Ninety-five percent confidence intervals (95% CI) were calculated for all parameters described in this section. The methods for these calculations were described in Summers, *et al* (1993b). Table 2-10 provides these intervals for the major indicators for the proportion of the province and the three estuarine classes.

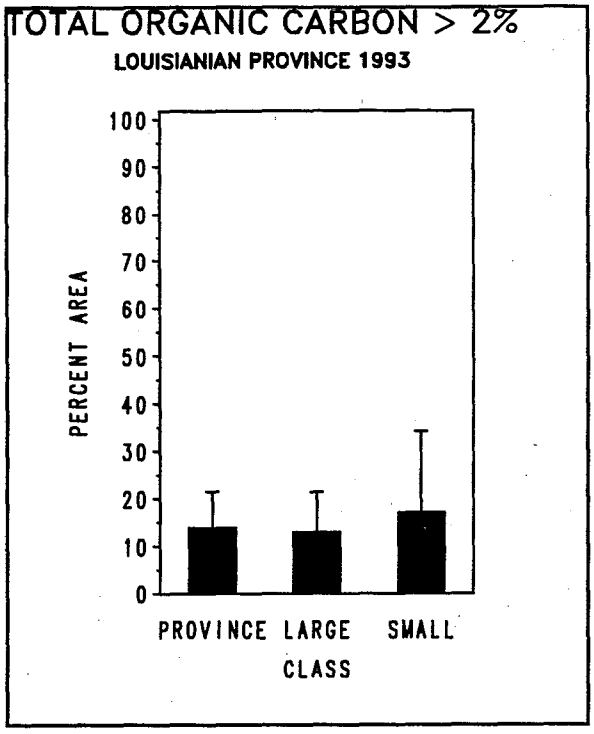


Figure 2-72. Percent area of estuaries with TOC > 2% in large estuaries, small estuaries, and the entire Province.

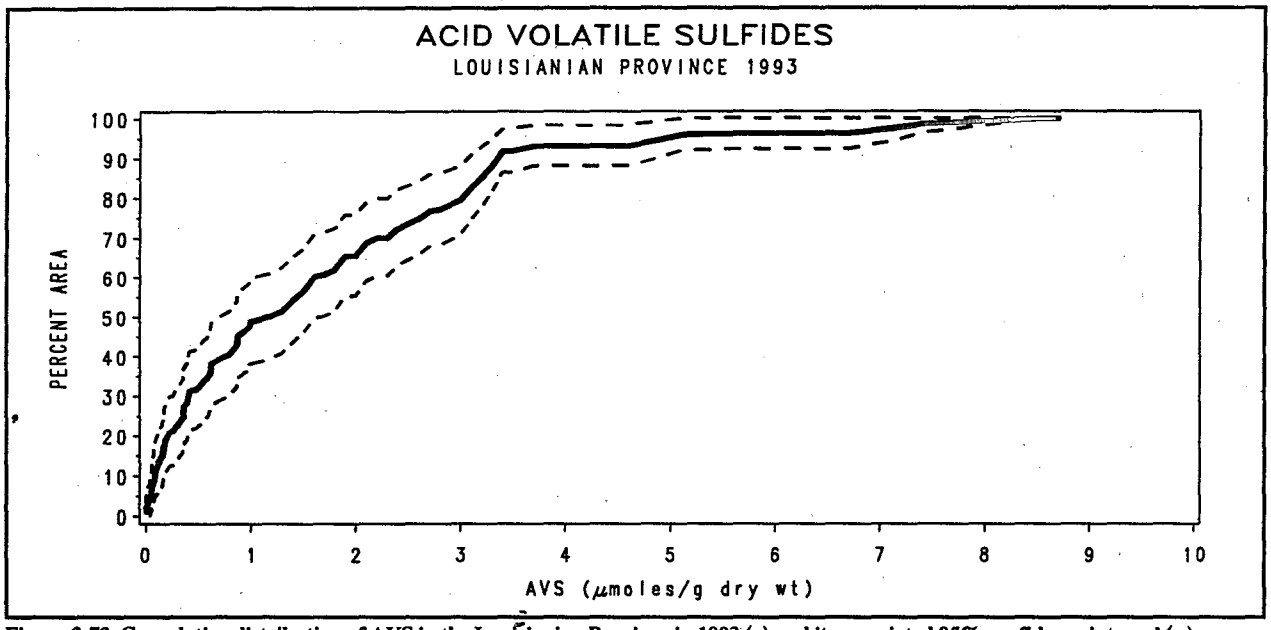


Figure 2-73. Cumulative distribution of AVS in the Louisianian Province in 1993 (–) and its associated 95% confidence interval (--).

Parameter	Province	Large Estuary	Small Estuary
N	93	62	31
ABIOTIC CONDITION			
Marine Debris	11(7)	10(7)	14(18)
Water Clarity			
PAR < 10%	18(8)	16(9)	22(18)
PAR < 25%	45(12)	44(18)	45(27)
Silt-Clay Content			
< 20%	21(9)	19(10)	26(19)
> 80%	35(11)	34(12)	38(25)
Alkanes			
Total > 7000 ppb	0(0)	0(0)	0(0)
PAHs			
Total > 4022 ppb	0(0)	0(0)	0(0)
PCBs			
Total > 22.7 ppb	<1(0)	0(0)	<1(1)
Pesticides			
Chlordane > .5 ppb	9(4)	11(8)	3(15)
Dieldrin > .02 ppb	67(10)	75(11)	42(26)
Endrin > .02 ppb	23(9)	26(11)	12(12)
DDT > 1 ppb	< 1(1)	0(0)	2(3)
DDE > 2 ppb	1(2)	2(3)	0(0)
DDD > 2 ppb	0(0)	0(0)	0(0)
Metals			
Ag > 1 ppm	0(0)	0(0)	0(0)
As > 8.2 ppm	33(11)	35(12)	25(24)
Cd > 1.2 ppm	1(2)	0(0)	5(9)
Cr > 81 ppm	9(6)	11(8)	0(0)
Cu > 34 ppm	0(0)	0(0)	0(0)
Hg > .15 ppm	2(3)	2(3)	5(9)
Ni > 20.9 ppm	35(6)	37(2)	27(24)
Pb > 46.7 ppm	0(0)	0(0)	0(0)
Sb > 2 ppm	0(0)	0(0)	0(0)
Zn > 150 ppm	4(4)	3(4)	5(9)
Tributyltin			
TBT>0 ppb	91(6)	90(7)	94(10)
TBT>5 ppb	7(5)	8(7)	3(5)

Table 2-10. Estimates of the proportion of the Louisianian Province and estuarine classes experiencing the levels of the listed parameters and their associated 95% confidence interval in parentheses (*N=number of sampling*).

Parameter	Province	Large Estuary	Small Estuary
N	93	62	31
BIOTIC CONDITION			
Benthic Index	37(11)	34(12)	48(26)
Abundance < 10	5(5)	6(6)	2(3)
# Species < 2	< 1(0)	0(0)	1(1)
# Species≤5	14(7)	18(10)	5(4)
Fish			
Abundance < 2	11(7)	10(7)	17(19)
Abundance≤5	21(9)	20(10)	27(24)
# Species < 1	2(2)	2(3)	1(2)
# Species < 2	13(8)	12(8)	17(19)
Fish Pathology[1]	10(3)	11(4)	5(0)
Fish Contaminants[1]			
Shrimp			
All > FDA Limits	13(0)	0(0)	33(0)
Croaker			
All > FDA Limits	0(0)	0(0)	0(0)
Marine Catfish			
Hg > FDA Limits	2(1)	0(0)	2(0)
Others > FDA Limits	0(0)	0(0)	0(0)
Bottom DO[2] < 2 ppm	7(6)	10(7)	1(1)
Bottom DO[2] ≤5 ppm	32(11)	34(12)	30(25)
Minimum DO < 2 ppm	18(9)	20(10)	12(21)
Sediment Toxicity	1(2)	2(3)	1(2)

[1] Percentage based on sample size rather than estuarine area
[2] Instantaneous dissolved oxygen measurements

Table 2-10 (*cont.*) Estimates of the proportion of the Louisianian Province and estuarine classes experiencing the levels of the listed parameters and their associated 95% confidence interval in parentheses (*N=number of sampling*).

SECTION 3

SUMMARY OF CONCLUSIONS

The Demonstration Project in the Louisianian Province in 1993 produced thousands of pieces of information about the estuarine resources of the Gulf of Mexico and their present condition. The following discussion summarizes key information concerning the conduct of the demonstration and highlights the findings.

3.1 OVERVIEW OF PROVINCE CHARACTERISTICS

- The Louisianian Province is comprised of 25,725 km^2 of estuarine resources spanning from Anclote Anchorage, FL to the Rio Grande, TX.

- Estuarine resources are defined as those water bodies located between sources of freshwater and the Gulf of Mexico, bounded on the seaward region by barrier islands and on the landward side by head of tide. For example, this would include as estuarine resources the lower Mississippi River from the delta to roughly New Orleans, LA and Apalachee Bay, FL, which is bordered on the seaward margin by submerged barrier islands.

- All estuarine resources in the Louisianian province were divided among three estuarine classes: large estuaries, large tidal rivers, and small estuaries/tidal rivers. Their delineation was based primarily on size.

- Large estuaries include Laguna Madre, Baffin Bay, Corpus Christi Bay, San Antonio Bay, Matagorda Bay, Galveston Bay, Calcasieu Lake, Vermilion Bay, Cote Blanche Bays, Atchafalaya Bay, Terrebone/Timbalier Bays, Caillou Bay, Barataria Bay, Chandeleur Sound, Breton Sound, Lake Borgne, Lake Pontchartrain, Lake Maurepas, Lake Salvador, Mississippi Sound, Mobile Bay, Bon Secour Bay, Pensacola Bay, Choctawhatchee Bay, St. Andrews Bay, St. George Sound and Apalachee Bay.

- Large tidal river class is comprised solely of the Mississippi River.

- Small estuary/tidal river class incorporates 165 estuarine systems between 2 to 260 km^2 of which 31 were selected for sampling in 1993.

- The total area of estuarine resources in the Louisianian Province can be subdivided among these three estuarine classes: large estuaries comprise km^2 (72%), large tidal rivers constitute 138 km^2 (<1%), and small estuaries make up km^2 (28%). Thus, province-wide conclusions, based on areal weighting, will be dominated by information from the large estuaries.

- 154 stations were selected for sampling using multiple indicators of estuarine

condition (e.g., benthic abundance, fish community composition, sediment chemistry, sediment toxicity).

- 9 selected sites could not be sampled due to insufficient depth (< 1 m). In terms of areal extent, these sites represent 6% of the estuarine resources in the province. The majority of these unsampleable sites occurred in the shallow zones of large estuaries.

- 10 Mississippi River sites could not be sampled due to flood conditions.

3.2 CONCLUSIONS OF THE 1993 SAMPLING

- Nearly 46% of the Louisianian Province estuarine resources were determined to be degraded in terms of biotic integrity or human use indicators. Twenty-nine (±6%) percent of the province experienced only low levels of biotic integrity, 8±11% experienced either marine debris or poor water clarity, and 9±6% experienced both forms of degradation.

- About 11±7% of the bottom sediments in Louisianian Province estuaries were littered with marine debris.

- 18±8% of the estuarine waters in the province had poor water clarity with > 10% ambient light reaching 1.0 meter.

- Estuarine sediments in the Louisianian Province generally contained concentrations of organic contaminants that were below criteria values expected to result in significant ecological effects. Endrin and Dieldrin were above these criteria for 18 to 57% of the sediments (respectively).

- Louisianian Province sediments were shown to be enriched with several heavy metals. Three to 17% of Louisianian Province sediments were enriched with at least one metal (arsenic, cadmium, chromium, mercury and zinc).

- Metal enrichment was observed in large and small estuarine resources.

- Approximately 10±7% of the sediments in the Louisianian Province (2050 km^2) proved to be toxic to Mysids while only 1±2% of sediments were toxic to Ampelisca.

- Tributyltin was measurable in 31±11% of Louisianian Province sediments; however, only 3±3% of sediments had 7±5% concentrations > 5 ppb.

- The edible portions of shrimp, Atlantic croaker, and catfish contained contaminant concentrations below FDA limits for PCBs, and pesticides. Shrimp, croakers and catfish contained levels of arsenic, chromium, and selenium in their edible tissues that was higher than international standards. Nine percent of the shrimp exceeded 2 ppm arsenic, 15 ppm copper, and 1 ppm mercury, with 4% exceeding 1 ppm selenium. A total of 5% of the croaker exceeded criteria for arsenic, 4% for cadmium, 2% lead and selenium, and 1% chromium and copper. Sixty-two percent of the catfish exceeded criteria for arsenic, 5% lead, and 1% chromium and mercury.

SECTION 4

REFERENCES

Agius, C. 1979. The role of melano-macrophage centers in iron storage in normal and diseased fish. J. Fish Dis. 2:337-343.

Agius, C. 1980. Phylogenetic development of melano-macrophage centers in fish. J. Zool., London 191:111-132.

Agius, C. and Roberts, R.J. 1981. Effects of starvation on the melano-macrophage centers in fish. J. Fish Biol. 19:161-169.

ASTM (American Society of Testing and Materials). 1990. Standard guide for conducting 10-day static sediment toxicity tests with marine and estuarine amphipods. Annual Book of ASTM Standards Volume 11.04:1052-1075.

Blazer, V.S., D.E. Facey, J.W. Fournie, L.A. Courtney, and J.K. Summers. 1994. Macrophage aggregates as indicators of environmental stress. In: J.S. Stolen and T.C. Fletcher eds. Modulators of Fish Immune Responses, Volume 1. SOS Publications: Fairhaven, NJ. pgs. 169-186.

Boesch, D.F. and R. Rosenberg. 1981. Response to stress in marine benthic communities. Pages 179-200. In: G.W. Barret and R. Rosenberg, eds. Stress Effects on Natural Ecosystems. John Wiley and Sons, New York.

Chapman, P.M. 1988. Marine sediment toxicity tests. In: J.J. Lichtenberg, F.A. Winter, C.I. Weber and L. Fredkin, eds. Chemical and Biological Characterization of Sludges, Sediments, Dredge Spoils, and Drilling Muds. ASTM, Philadelphia, PA.

DiToro, D.M., J.D. Mahony, D.J. Hansen, K.J. Scott, A.R. Carlson, G.T. Ankley. 1991. Acid volatile sulfide predicts the acute toxicity of cadmium and nickel in sediments. 201st ACS National Meeting of the American Chemical Society, Atlanta, Georgia USA. April 14-19, 1991. Abstr. PAP Am. Chem. Soc. 201:1-2.

Ellis, A.E., Munro, A.L.S., and Roberts, R.J. 1976. Defense mechanisms in fish. I. A study of the phagocytic system and the fate of intraperitoneally injected particulate material in plaice (Pleuronectes platessa). J. Fish Biol. 8:67-78.

Engle, V.D., J.K. Summers and G.R. Gaston. 1994. A benthic index of environmental condition of Gulf of Mexico estuaries. Estuaries 17:372-384.

Ferguson, H.W. 1976. The relationship between ellipsoids and melano-macrophage centers in the spleen of turbot (Scopthalmus maximus). J. Comp. Path. 86:377-380.

Karr, J.R. and D.R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Management 5:55-68.

Klinkhammer, G.P. and M.L. Bender. 1981. Trace metal distributions in the Hudson River estuary. Estuarine, Coastal and Shelf Science 12: 629-643.

Lake, J.L., C. Norwood, C. Dimock and R. Bowen. 1979. Origins of polycyclic aromatic hydrocarbons in estuarine sediments. Geochimica et Cosmochimica Acta 43:1847-1854.

Laughlin, R.B., K. Nordlund, and O. Linden. 1984. Long-term effects of tributyltin compounds on the Baltic amphipod, *Gammarus oceanicus*. Mar. Environ. Res. 12:243-271.

Long, E.R. and L.G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52. US Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Rockville, MD.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within the ranges of chemical concentrations in marine and estuarine sediments. Environmental Management 19:81-97.

Messer, J.J. 1990. EMAP indicator concepts. Chapter 2. In C.T. Hunsaker and D.E. Carpenter (eds) Ecological indicators for the Environmental Monitoring and Assessment Program. EPA 600/3-90/060. U.S. Environmental Protection Agency, Office of Research and Development, Research Triangle Park, NC.

Nauen, C.E. 1983. Compilation of legal limits for hazardous substances in fish and fishery products. FAO fisheries Circular No. 764, Food and Agriculture Organization of the United Nations, Rome, Italy, 102 pp.

Nixon, S.W., C.D. Hunt and B.L. Nowicki. 1986. The retention of nutrients (C,N,P), heavy metals (Mn, Cd, Pb, Cu), and petroleum hydrocarbons in Narragansett Bay. Pages 99-122. In: P. Lasserre and J.M. Martin, eds. Biogeochemical Processes at the Land-sea Boundary Elsevier, NY.

Pearson, T.H. and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. Mar. Biol. Ann. Rev. 16:229-311.

Ross, J.B., R. Parker and M. Strickland. 1991. A survey of shoreline litter in Halifax Harbour 1989. Marine Pollution Bulletin 22:245-248.

Schropp, S.J., F.G. Lewis, H.L. Windom, J.D. Ryan, F.D. Calder and L.C. Burney. 1990. Interpretation of metal concentrations in estuarine sediments of Florida using aluminum as a reference element. Estuaries 13:227-235.

Schubel, J.R., and H.H. Carter. 1984. The estuary as a filter for fine-grained suspended sediment. pgs. 81-104. In: V.S. Kennedy, ed. The Estuary as a Filter. Academic Press, Orlando, FL.

Summers, J.K. and V.D. Engle. 1993. Evaluation of sampling strategies to characterize dissolved oxygen conditions in northern Gulf of Mexico estuaries. Environmental Monitoring and Assessment 24:219-229.

Summers, J.K., J.M. Macauley, and P.T. Heitmuller. 1991. Implementation plan for monitoring the estuarine waters of the Louisianian Province - 1991. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Gulf Breeze, FL. EPA/600/R-91/228.

Summers, J.K., J.M. Macauley, V.D. Engle, G.T. Brooks, P.T. Heitmuller, and A.M. Adams. 1993a. Louisianian Province Demonstration Report: EMAP-Estuaries-1991. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Gulf Breeze, FL. EPA/600/R-94/001.

Summers, J.K., J.M. Macauley, P.T. Heitmuller, V.D. Engle, A.M. Adams, and G.T. Brooks. 1993b. Annual Statistical Summary: EMAP-Estuaries Louisianian Province - 1991. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Gulf Breeze, FL. EPA/620/R-93/007.

Summers, J.K., T.L. Wade, V.D. Engle, and Z.A. Malaeb. 1995. Normalization of metal concentrations in estuarine sediments from the Gulf of Mexico. Estuaries (in press).

Swartz, R.C., W.A. DeBen, J.K. Jones, J.O. Lamberson, and F.A. Cole. 1985. Phoxocephalid amphipod bioassay for marine sediment toxicity. Pages 284-307. In: R. D. Cardwell, R. Purdy, and R.C. Bahner, eds. Aquatic Toxicology and Hazard Assessment: Seventh Symposium. American Society for Testing and Materials, Philadelphia, PA.

Trefry, J.H., S. Metz, and R.P. Trocine. 1985. The decline of lead transport by the Mississippi River. Science 230:439-441.

USEPA. 1989. Briefing Report to the EPA Science Advisory Board on the equilibrium partitioning approach to generating sediment quality criteria. U.S. Environmental Protection Agency, Criteria and Standards Division, Washington, DC. EPA 440/5-89-002.

USFDA (United States Food and Drug Administration). 1982. Levels for poisonous or deleterious substances in human food and animal feed. U.S. Food and Drug Administration, Washington, D.C., 13 pp.

USFDA (United States Food and Drug Administration). 1984. Polychlorinated biphenyls (PCBs) in fish and shellfish; reduction of tolerances; final decision. U.S. Food and Drug Administration, Rockville, MD. Federal Register 49: 21514-21520.

Weiss, J.S. and J. Perlmutter. 1987. Effects of tributyltin on activity and burrowing of the fiddler crab, Uca pugilator. Estuaries 10:342-346.

Weis, J.S. 1988. Action on antifouling paints. BioScience 38:90-92.

Windom, H.L., S.J. Schropp, F.D. Calder, J.D. Ryan, R.G. Smith, L.C. Burney, F.G. Lewis and C.H. Ralinson. 1989. Natural trace metal concentrations in estuarine and coastal marine sediments of the southeastern United States. Environmental Science and Technology 23: 314-320.

Wolke, R.E., Murchelano, R.A., Dickstein, C.D., and George, C.J. 1985. Preliminary evaluation of the use of macrophage aggregates (MA) as fish health monitors. Bull. Environ. Contam. Toxicol. 35:222-227.

APPENDIX A

SUBPOPULATION ESTIMATION BASED ON EMAP SAMPLING

One of the major advantages of the probability-based sampling design used by all elements of the Environmental Monitoring and Assessment Program (EMAP) is the ability to use the data to address questions and/or objectives other than those specified by the program. Essentially, the only negative aspect associated with these additional analyses is an increase in the uncertainty associated with the estimates due to a decrease in the sample size (i.e., not all the data are used). This process is called "subpopulation estimation." For EMAP-E, for example, the process might involve using a specific portion of the collected data to examine a question concerning a subset of the ecological community (i.e., only surface measures), a subset of estuarine resources (e.g., those in a particular state or EPA Region), or a subset for an individual estuary (e.g., Galveston Bay, Mississippi Sound).

In this appendix, all of the major ecological indicators described in Chapter 2 are evaluated in terms of state specific resources. The statistical methods used to perform this level of evaluation are the same as used in the Province analysis but are adapted to the estuarine resources of each estuarine class within the boundaries of each of the five Gulf states.

A.1 BIOTIC CONDITION INDICATORS

Biotic condition indicators are characteristics of the environment that provide quantitative evidence of the status of ecological resources and biological integrity at a sampling site. Biotic condition measures examined here include measurements of the kinds and abundances of biota present and human use parameters that describe human perceptions of the condition of estuarine systems. No state-level estimates have been made for fish pathologies or tissue contaminant levels. Subpopulation estimation for these indicators, based on spatial reduction, is not possible without using complex statistical methods to fit spatial response surfaces to estimate these indicators where fish were not collected in adequate numbers.

The following presentation does not represent all the analyses completed at the state-level for each indicator. For example, a set of five individual state CDFs and pie charts exist for each indicator, but only one CDF and pie chart for a selected state will be shown in this appendix. However, the proportion of estuarine resources in each state associated with the criterion for subnominal condition is shown in the bar charts.

The uncertainty associated with the state estimates is directly proportional to the total number of sites within the state boundaries. This uncertainty ranges, in general, from a low of about 5 to 7% for Louisiana (N=38) to a high for Mississippi of approximately 20 to 30% (N=7). The 95% confidence intervals are shown for each CDF shown in Appendix A and in tabular form for all states at the end of the appendix.

Although the sample size for Alabama estuarine waters is small (N=7), the corresponding variance estimates are also small (see Table A-1).

A.1.1 BENTHIC INDEX

The construction of the benthic index is described in Summers et al. (1993b) and Engle et al. (1993). The cumulative distribution functions for the benthic index in Mississippi and Texas are shown in Figures A-1 and A-2. About 7±5% of the estuarine sediments in Mississippi contained benthic communities similar to those observed at known environmentally-degraded sites (Fig. A-3). The highest proportions of degraded benthic communities within the Gulf states in 1993 were still found in Louisiana and Texas (Fig. A-4).

A.1.2 NUMBER OF FISH SPECIES

Total number of fish species has been used to characterize the environmental condition of estuarine habitats. A single 10-min trawl, taken at each sampling in the Louisianian Province, resulted in a distribution of total number of species for sites in Louisiana and Texas shown in Figures A-5 and A-6. About 7±8% of the estuarine waters in Louisiana produced < 2 species in a single 10-min trawl (Fig. A-7). Seven (±8) to 8±13% of the estuarine waters in Louisiana and Florida were characterized by these small numbers of species (Fig. A-8).

A.1.3 MARINE DEBRIS

The presence of marine debris is one of the obvious indicators of estuarine "degradation" from a human use perspective. Over 17% of the estuarine sediments in Louisiana contained marine debris, with about 3% of Florida and 12% in Texas estuarine sediments containing marine debris (Fig. A-9).

A.1.4 WATER CLARITY

Another social or human use criterion for good estuarine condition is water clarity. Water clarity was measured using a comparison of surface ambient light and the amount of light reaching 1 meter in depth. The cumulative distribution function for water clarity in Louisiana is shown in Fig. A-10 where proportional light reaching 1 meter ranged from 0-50%. A value of 10% transmittance reaching a depth of one meter was used as a measure of turbid conditions. Most of the water of lower transmissivity in Gulf estuaries is located in Louisiana (30±12%) and Texas (42±27%) (Fig. A-11).

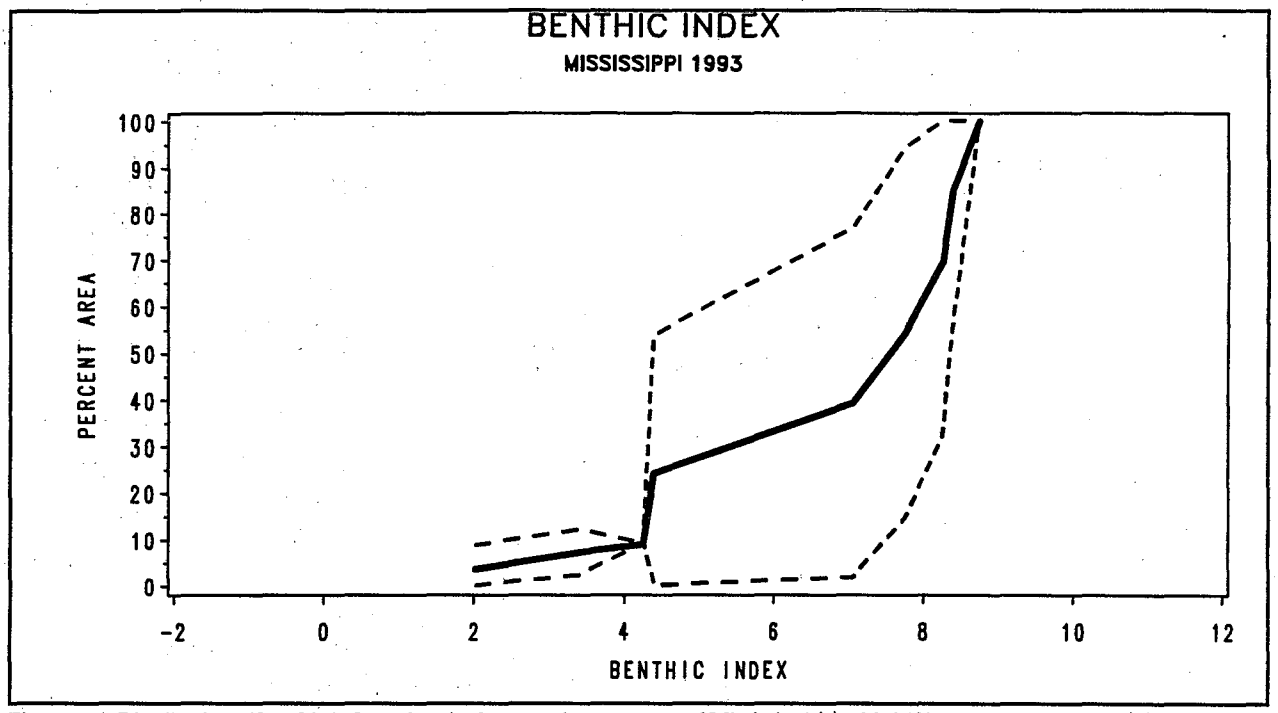


Figure A-1. Distribution of benthic index values in the estuarine resources of Mississippi (–) with 95% confidence intervals (--).

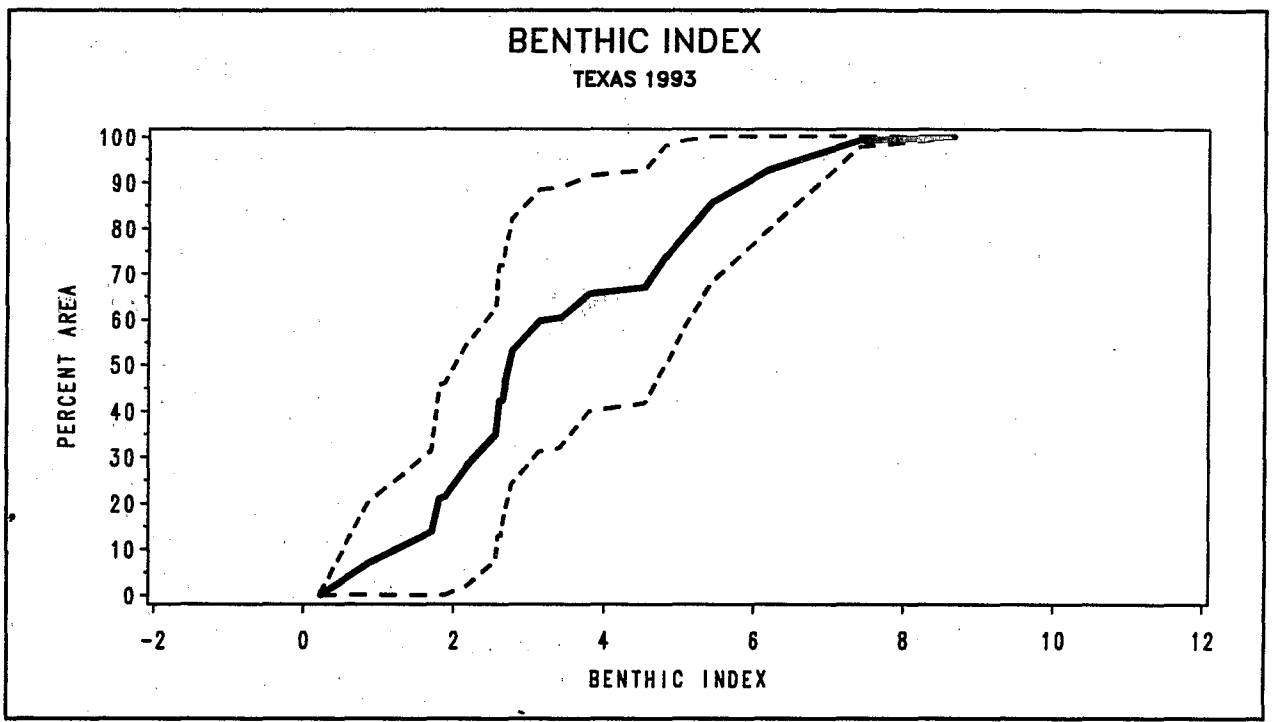


Figure A-2. Distribution of benthic index values in the estuarine resources of Texas (–) with 95% confidence intervals (--).

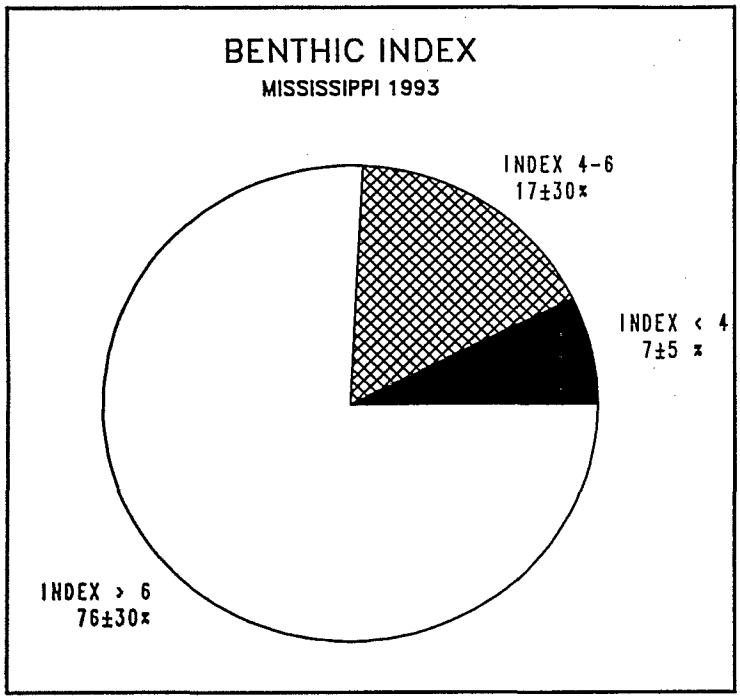


Figure A-3. Proportion of Mississippi estuarine resources with benthic index values in selected categories.

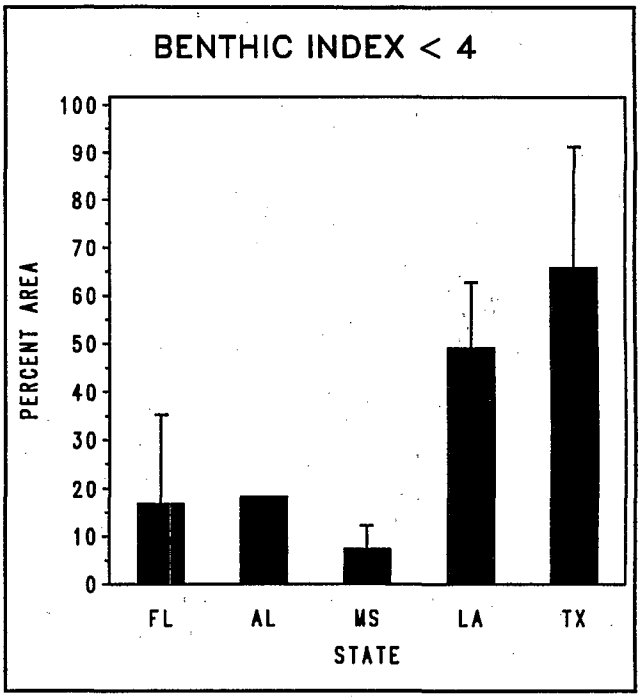


Figure A-4. Proportion of Gulf states' estuarine resources with benthic index values < 4.0, with 95% confidence interval.

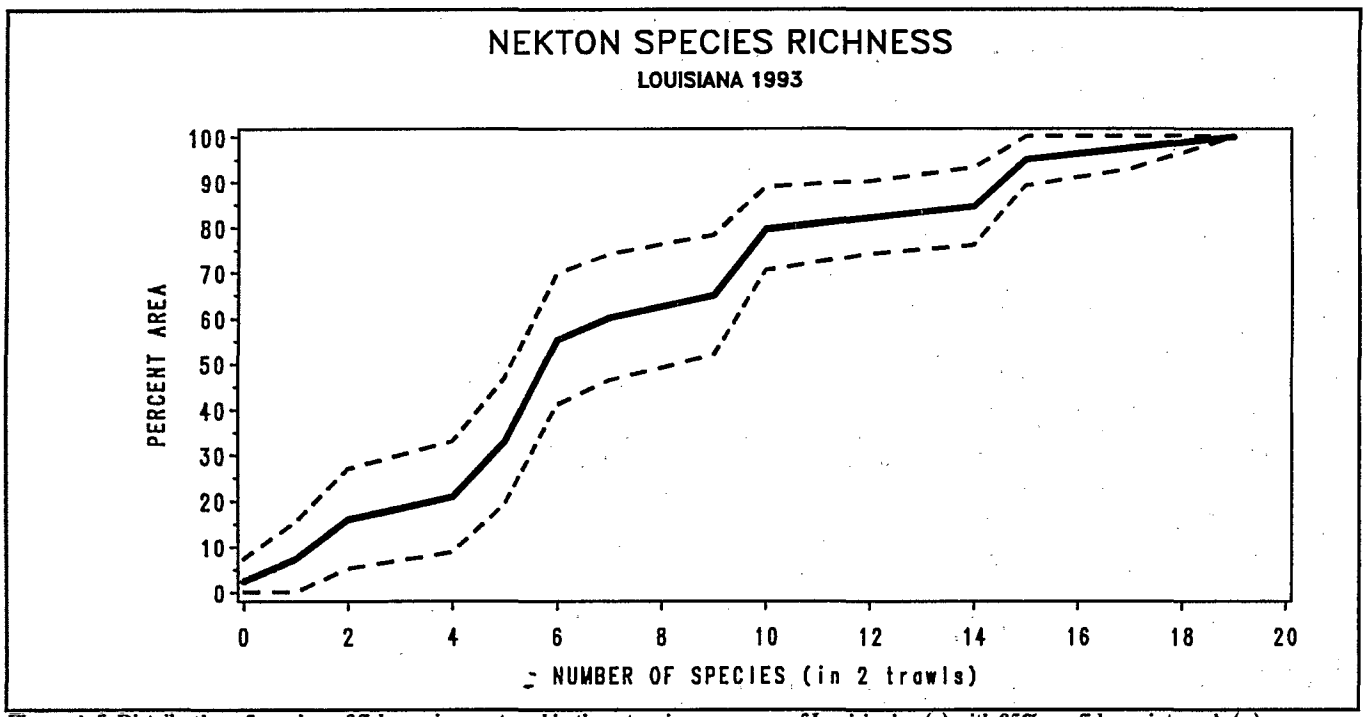


Figure A-5. Distribution of number of fish species per trawl in the estuarine resources of Louisianian (–) with 95% confidence intervals (--).

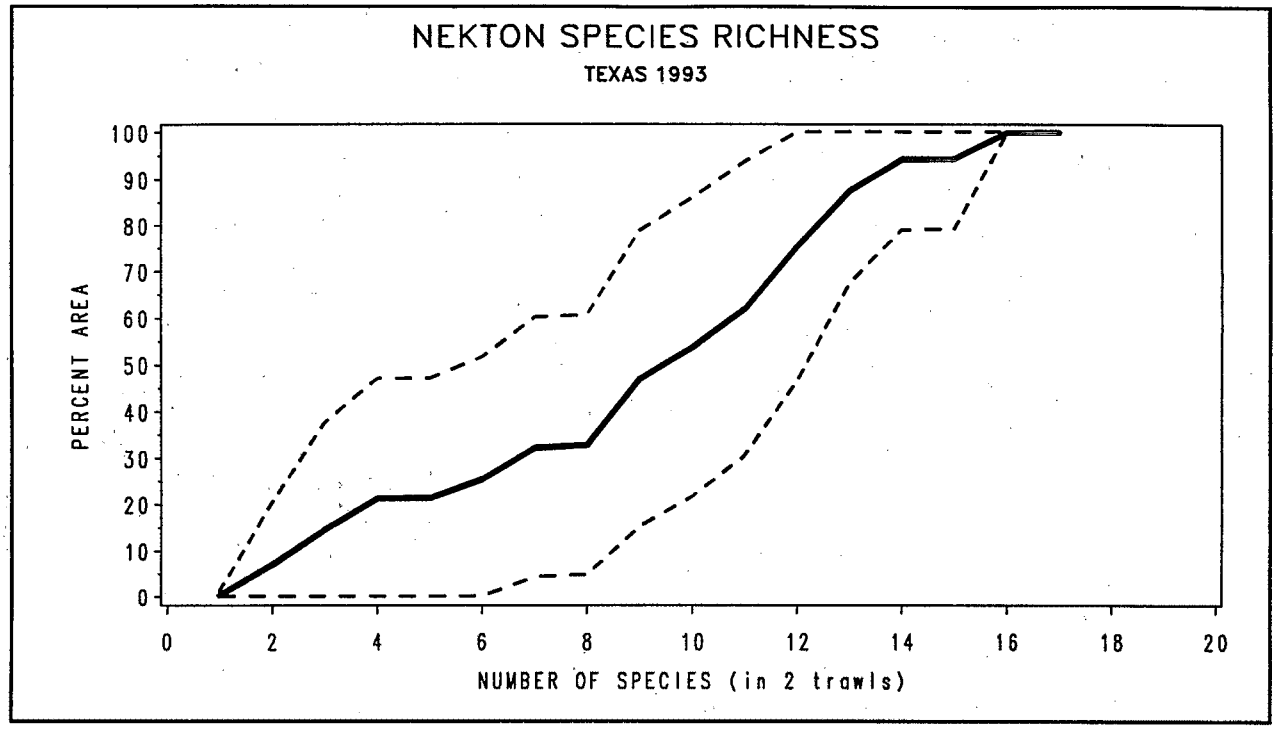


Figure A-6. Distribution of number of fish species per trawl in the estuarine resources of Texas (–) with 95% confidence intervals (--).

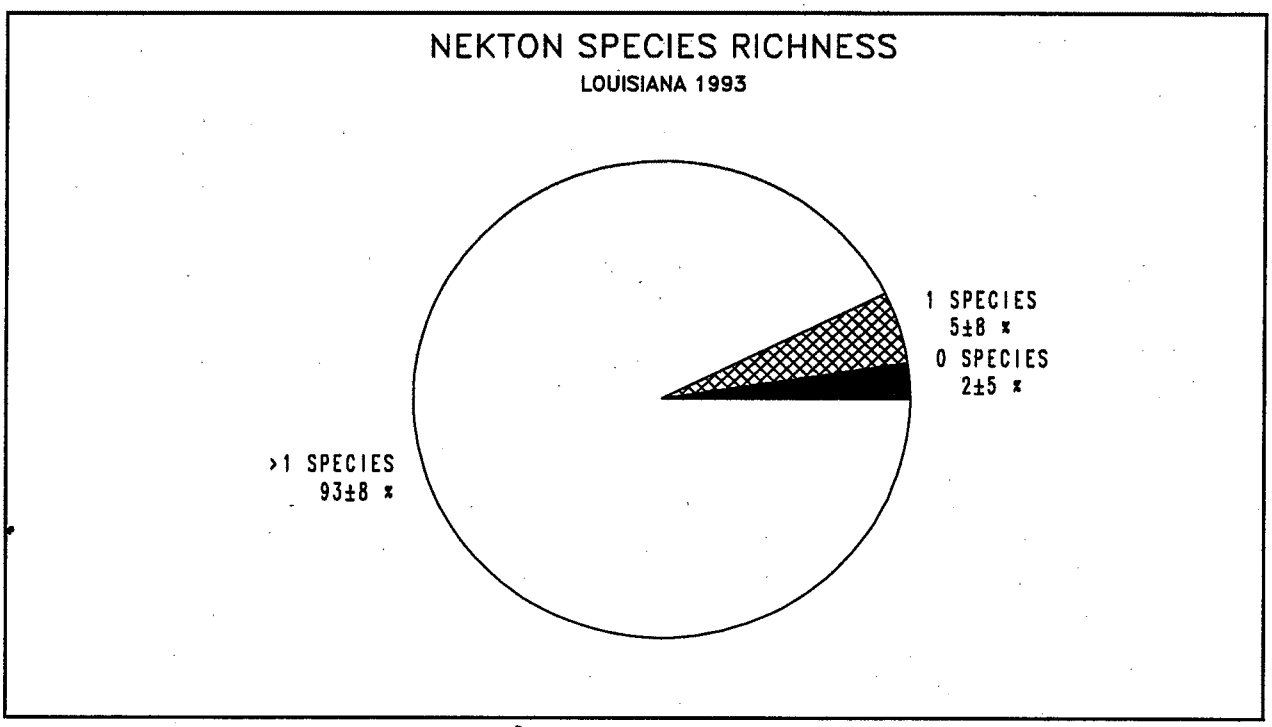


Figure A-7. Proportion of Louisiana estuarine resources with number of fish species per trawl in selected categories.

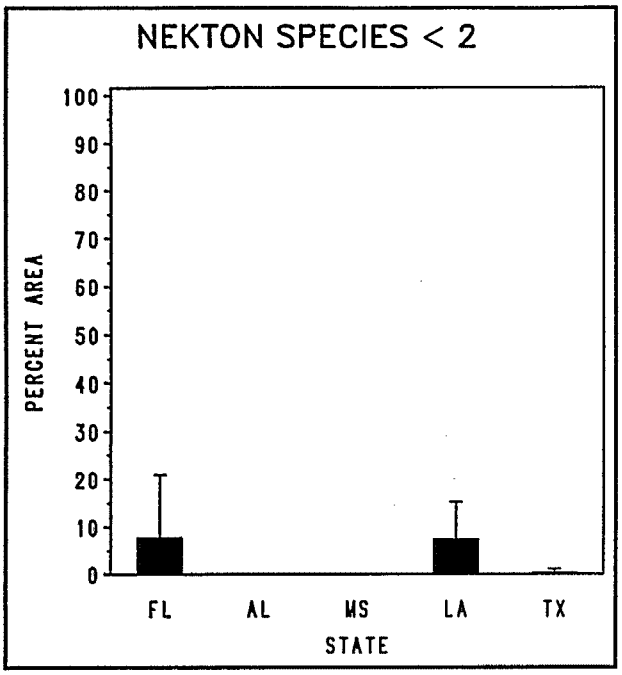


Figure A-8. Proportion of Gulf states' estuarine resources with number of fish species per trawl ≤ 1, with 95% confidence interval.

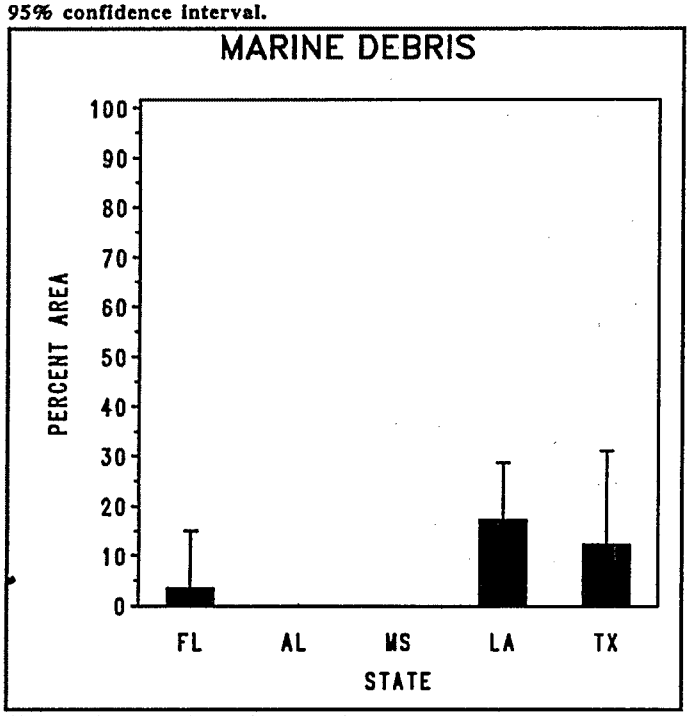


Figure A-9. Proportion of Gulf states' estuarine resources with marine debris present in bottom sediments, with 95% confidence interval.

A.1.5 INTEGRATION OF ESTUARINE CONDITIONS

A single index value has been developed to summarize the overall condition of the estuaries in the Louisianian Province by combining the benthic index, marine debris and water clarity, weighted equally. This single value can also be used to summarize the overall condition of estuaries in each of the Gulf states. Figure A-12 shows that 21±18% of the estuarine resources in the portion of Florida in the Louisianian Province were degraded with regard to biotic communities or human uses. Similar summarizations are shown in Figures A-13 through A-16 for Alabama, Mississippi, Louisiana and Texas and ranged from 7±5% degraded estuarine area in Mississippi to 71±22% in Texas.

A.2 ABIOTIC CONDITION INDICATORS

Abiotic condition indicators have historically been the mainstay of state environmental monitoring programs. The results for Gulf states are shown for dissolved oxygen, sediment toxicity, and sediment contaminants.

A.2.1 DISSOLVED OXYGEN (INSTANTANEOUS)

Dissolved oxygen (DO) concentration is a fundamental requirement of populations of benthos, fish, shellfish, and other aquatic biota. DO was measured in two ways: instantaneous point measures at 1-m depth intervals during the sampling and deployed continuous recordings of dissolved oxygen for a 24-hour period.

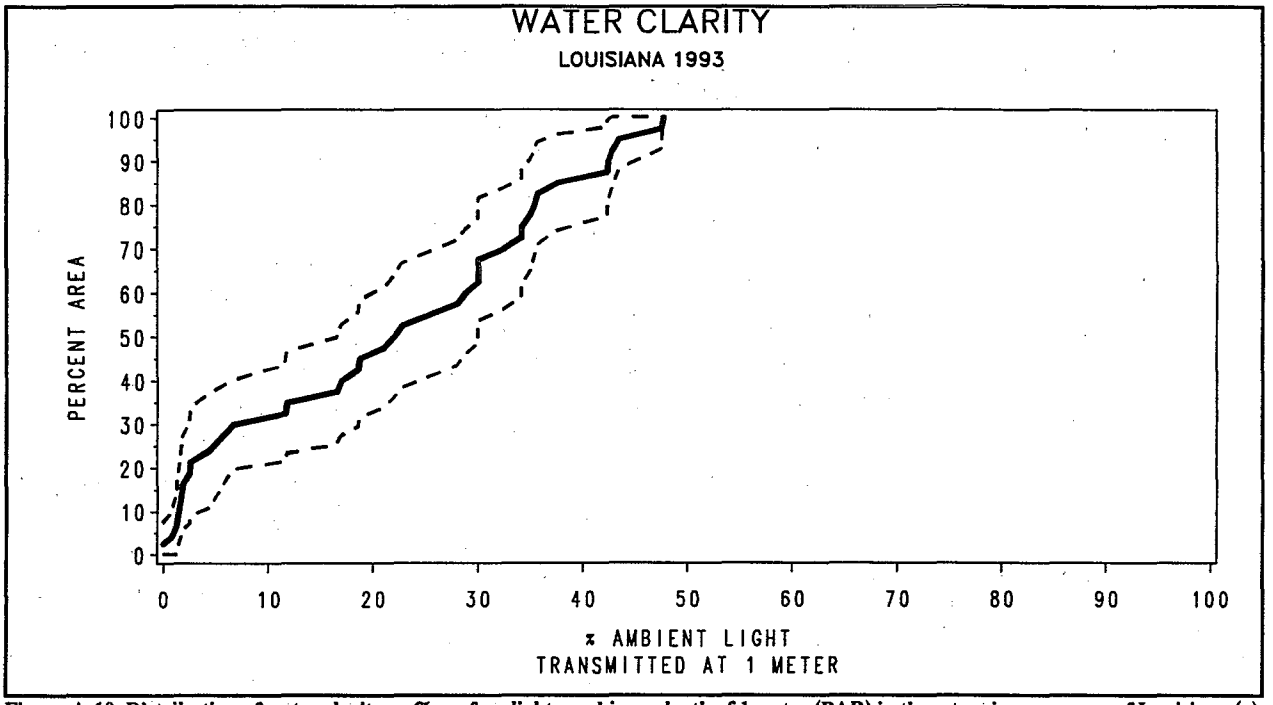


Figure A-10. Distribution of water clarity as % surface light reaching a depth of 1 meter (PAR) in the estuarine resources of Louisiana (–) with 95% confidence intervals (--).

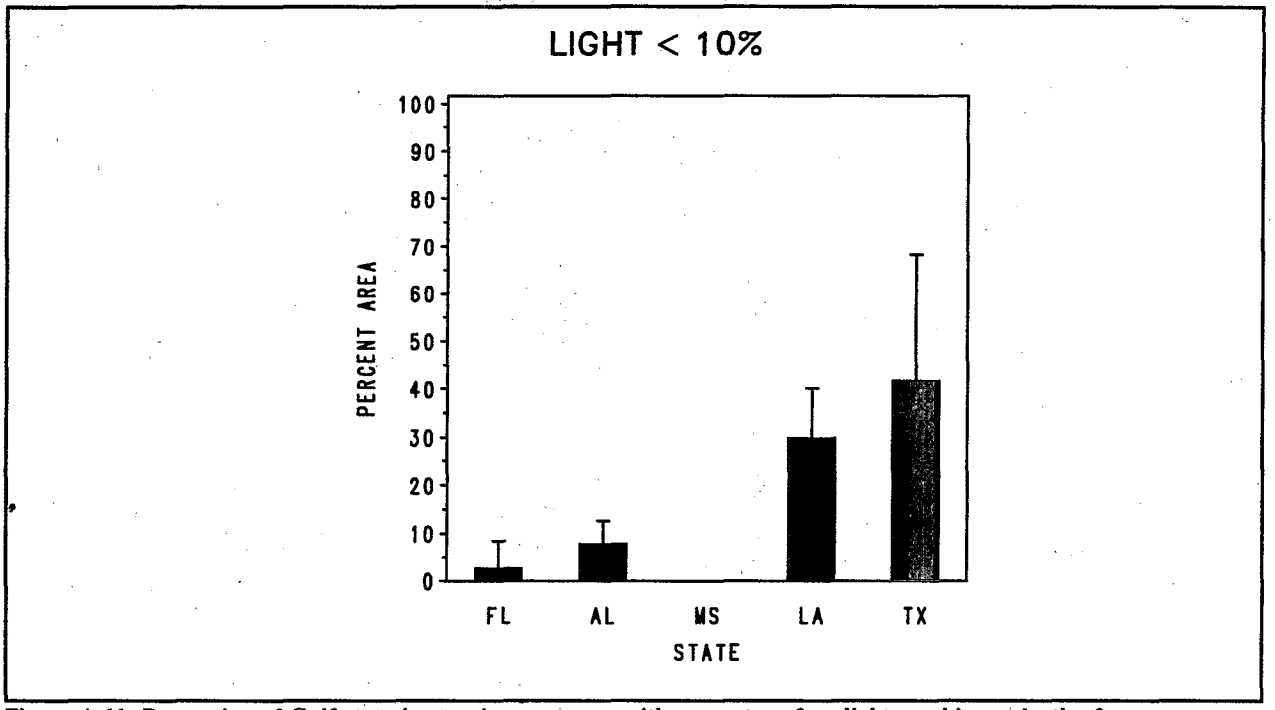


Figure A-11. Proportion of Gulf states' estuarine resources with percent surface light reaching a depth of one meter < 10%, with 95% confidence interval.

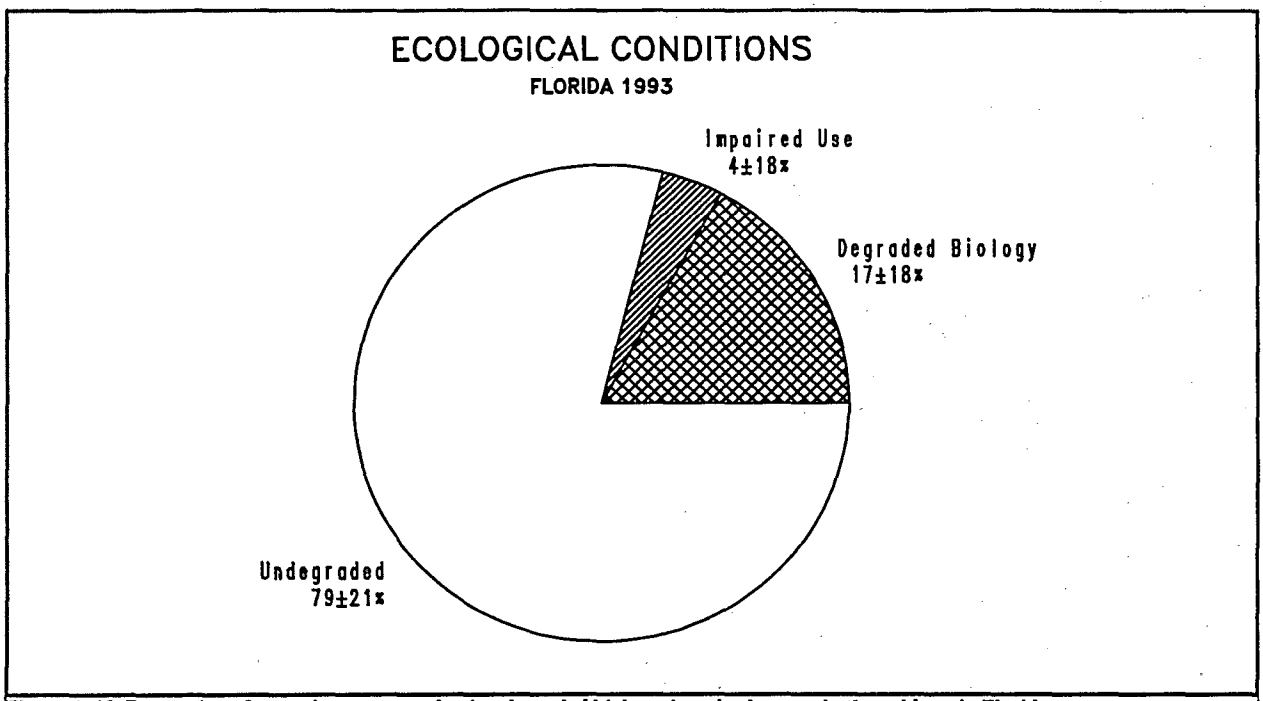


Figure A-12. Proportion of estuarine resources having degraded biology, impaired use, or both problems in Florida.

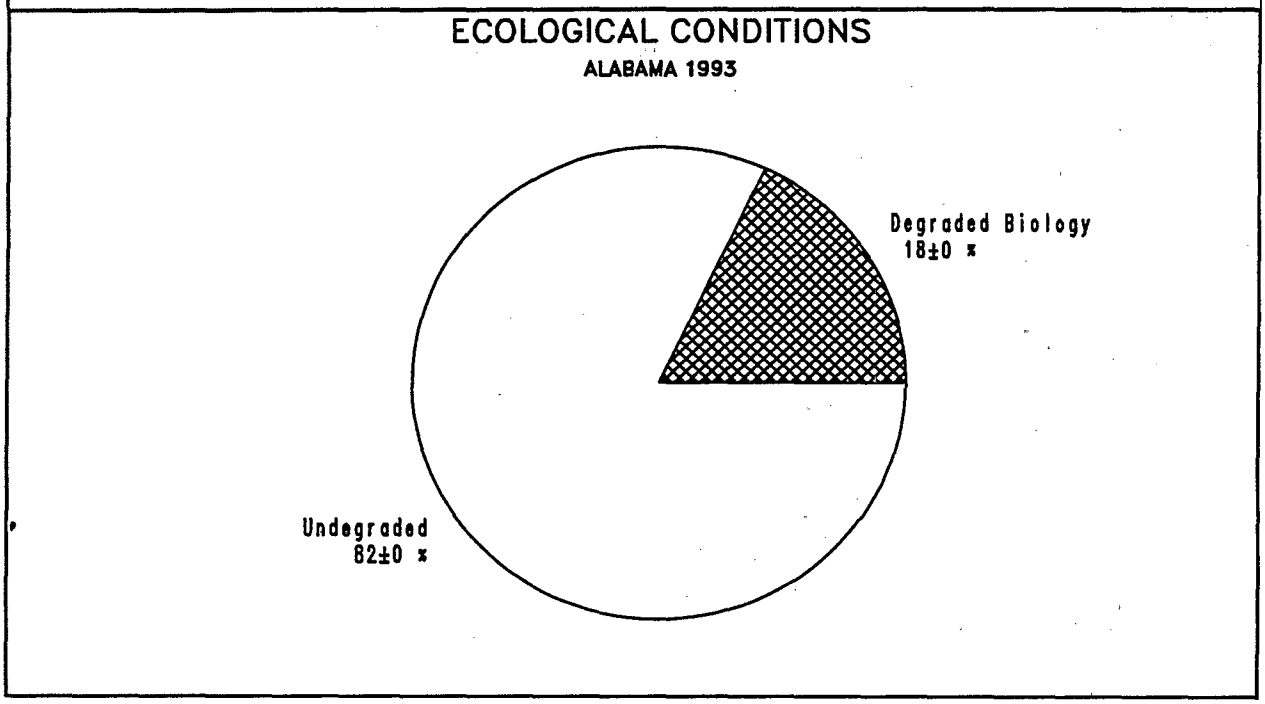


Figure A-13. Proportion of estuarine resources having degraded biology, impaired use, or both problems in Alabama.

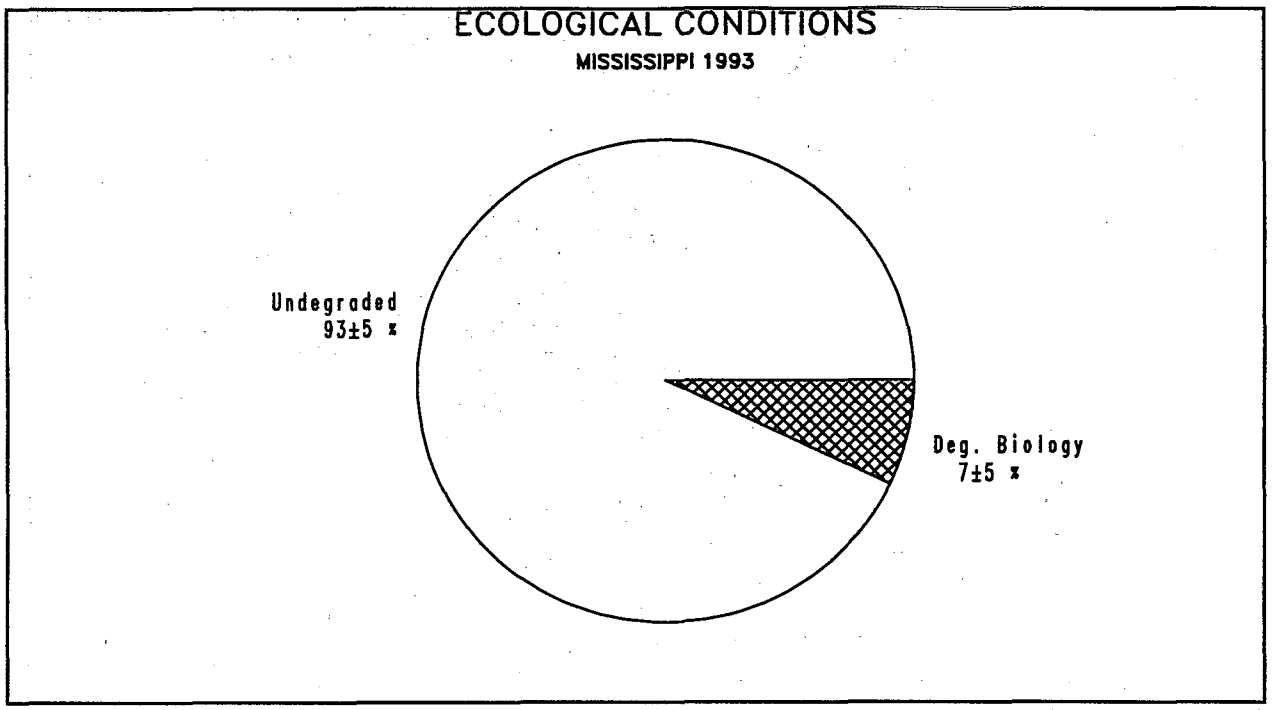


Figure A.14. Proportion of estuarine resources having degraded biology, impaired use, or both problems in Mississippi.

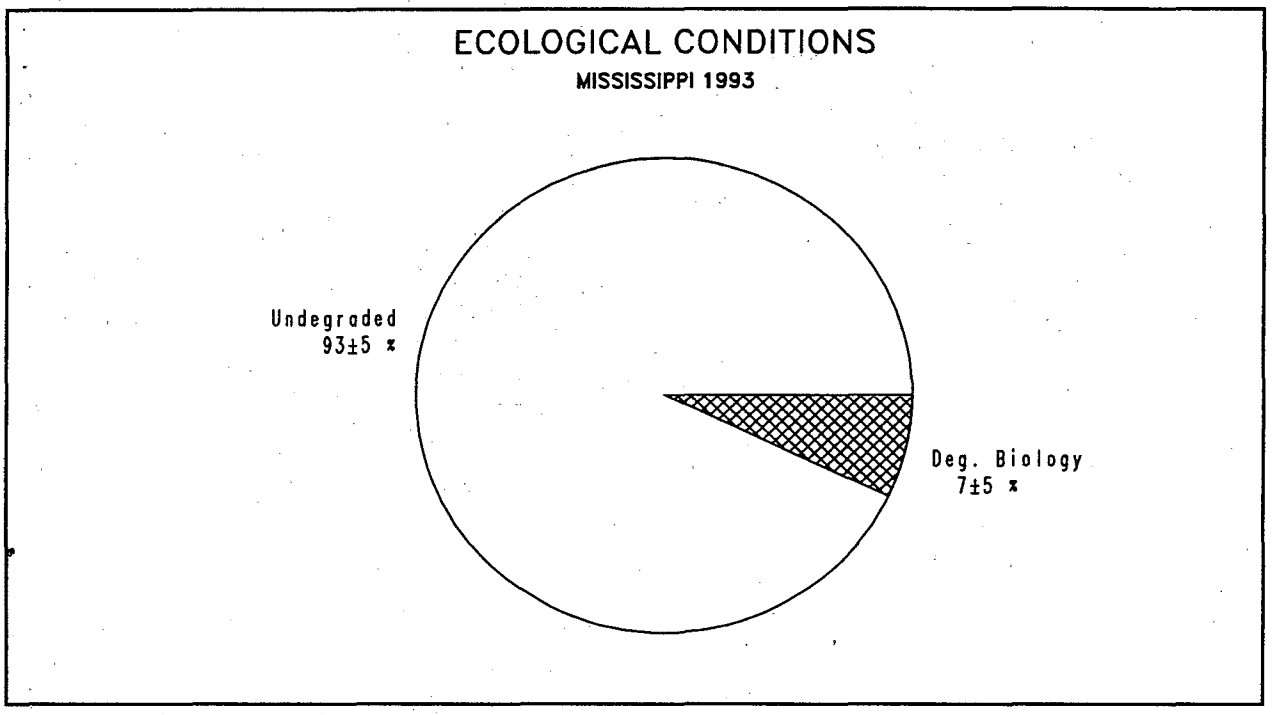


Figure A.15. Proportion of estuarine resources having degraded biology, impaired use, or both problems in Mississippi.

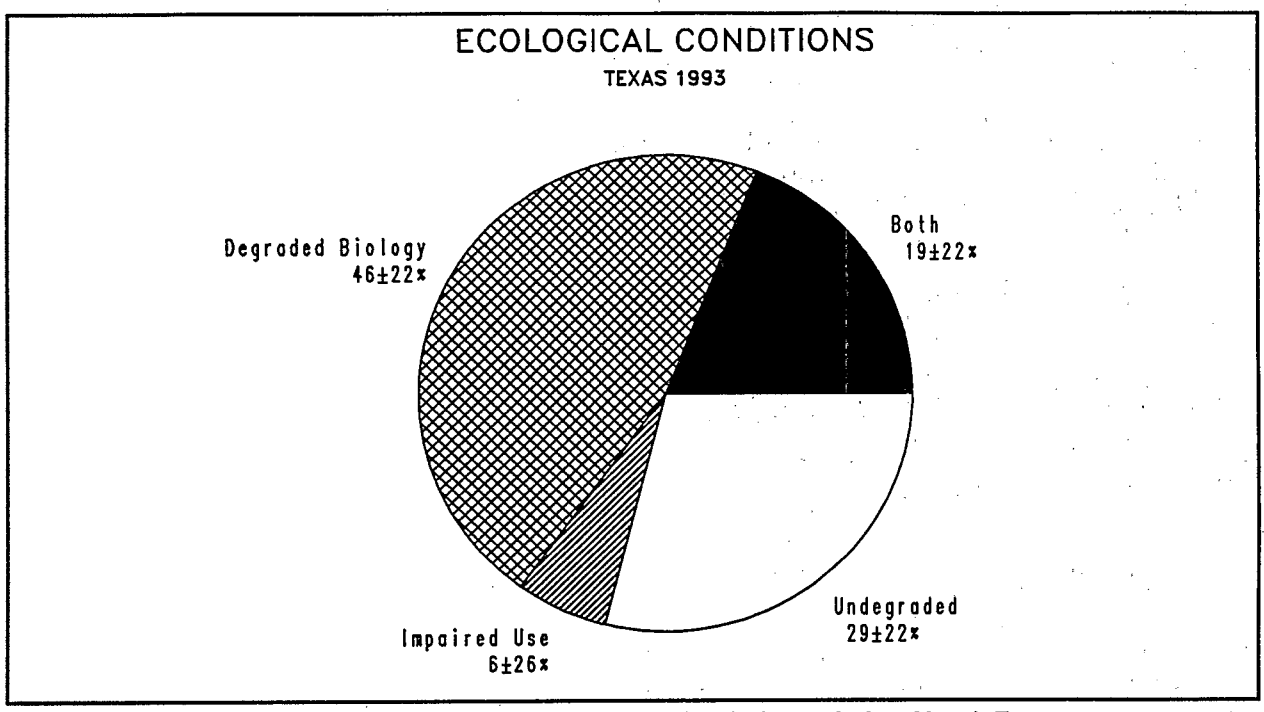


Figure A.16. Proportion of estuarine resources having degraded biology, impaired use, or both problems in Texas.

The cumulative distribution function of bottom dissolved oxygen in Florida estuaries is shown in Figure A-17. All Gulf states experienced DO conditions < 5 ppm Alabama, Louisiana and Florida predominated with almost 32 to 70%(±14 to 53) of their resources below this figure (Fig. A-18). All dissolved concentrations < 2 ppm were observed primarily in Louisiana and Alabama (Fig. A-19).

A.2.2 DISSOLVED OXYGEN (CONTINUOUS)

Unlike the instantaneous measures, the continuous dissolved oxygen concentration measurements provide a complete picture of the DO conditions at a site by including day and night conditions as well as all tidal conditions. The minimum bottom DO concentrations from the continuous measurements in Louisiana ranged from 0 to 10 ppm (Fig. A-20). Minimum dissolved oxygen concentrations below 2 ppm were most often observed in Alabama (Fig. A-21).

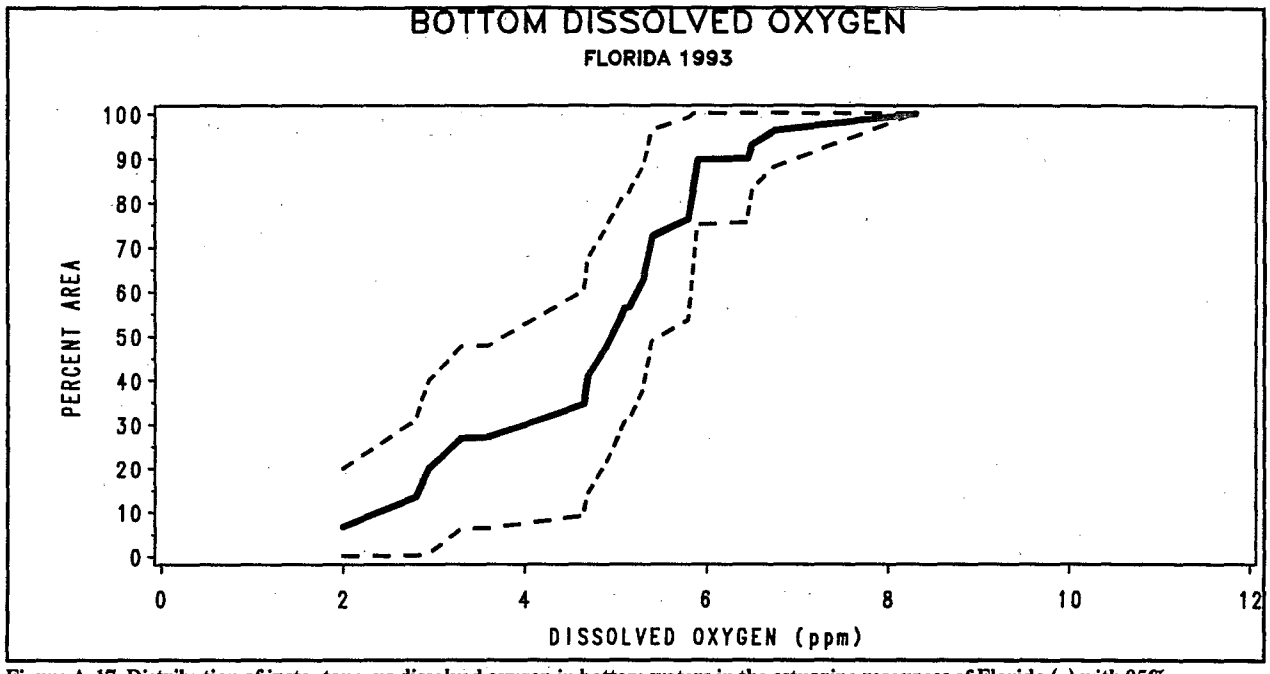


Figure A-17. Distribution of instantaneous dissolved oxygen in bottom waters in the estuarine resources of Florida (–) with 95% confidence intervals (--).

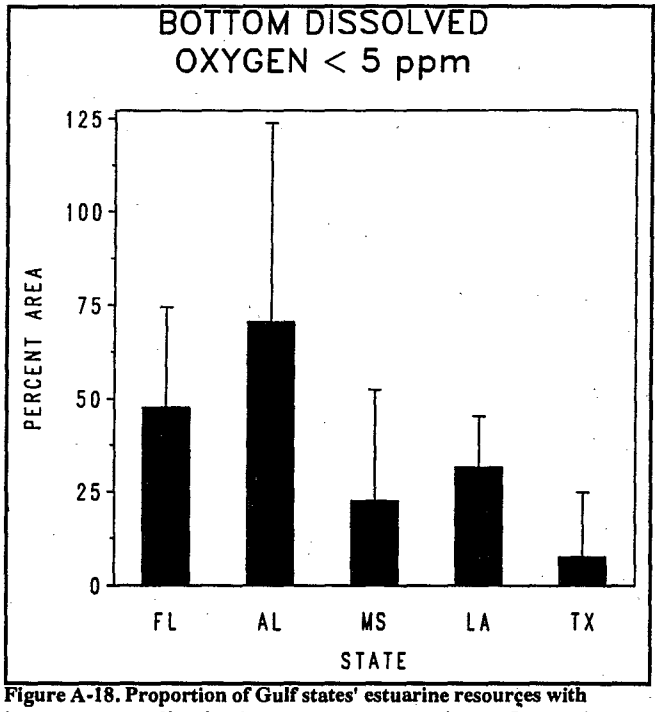


Figure A-18. Proportion of Gulf states' estuarine resources with instantaneous dissolved oxygen concentration < 5 ppm in bottom waters, with 95% confidence interval.

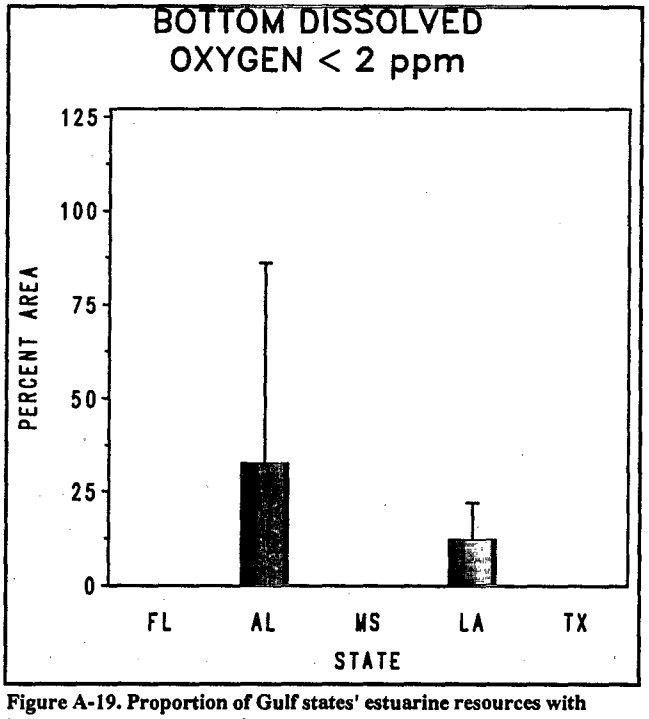


Figure A-19. Proportion of Gulf states' estuarine resources with instantaneous dissolved oxygen concentration < 2 ppm in bottom waters, with 95% confidence interval.

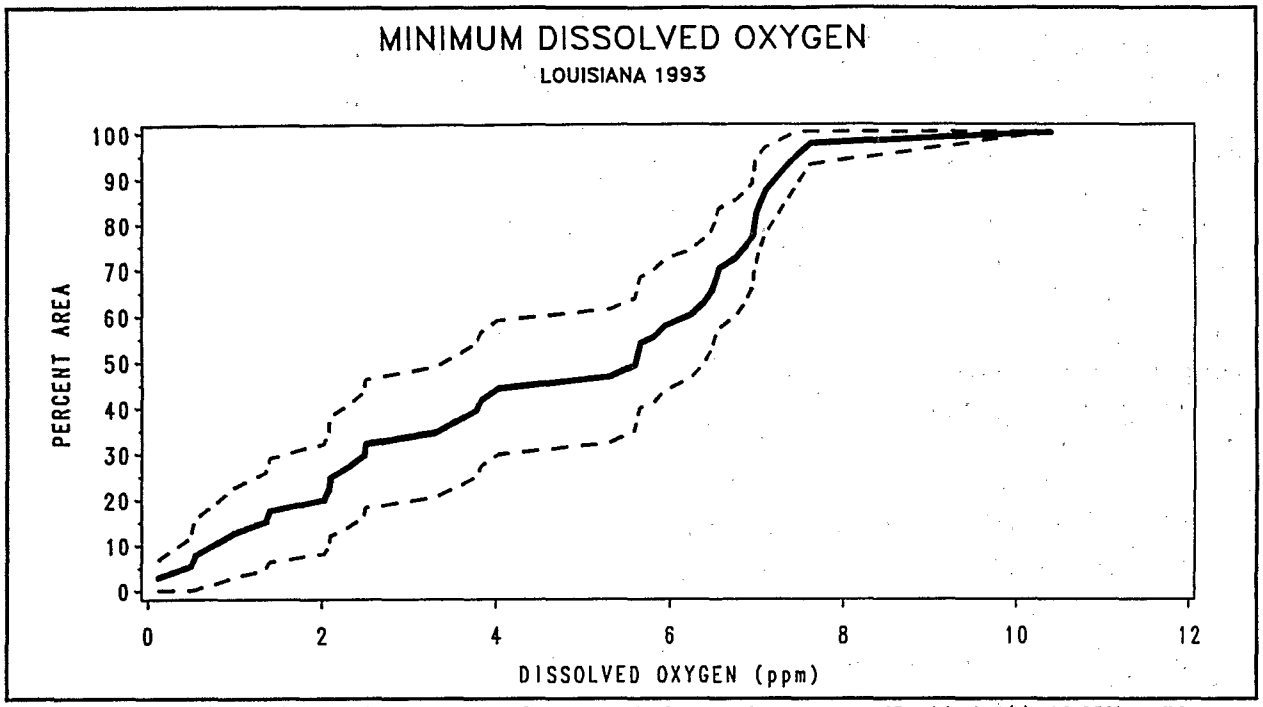


Figure A-20. Cumulative distribution of continuous dissolved oxygen in the estuarine resources of Louisianian (–) with 95% confidence intervals (--).

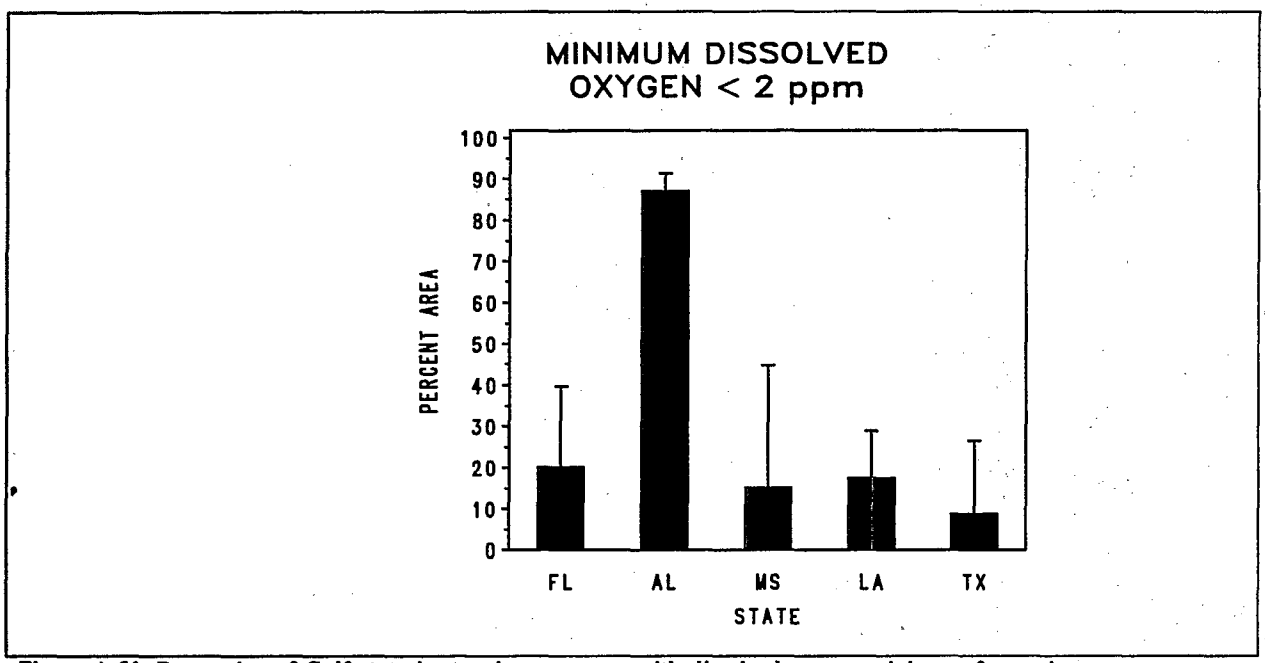


Figure A-21. Proportion of Gulf states' estuarine resources with dissolved oxygen minima < 2 ppm in bottom waters, with 95% confidence interval.

A.2.3 SEDIMENT TOXICITY - AMPELISCA ABDITA

Sediment toxicity tests were performed on the composited surface sediments collected from each sampling site. Tests included a 10-day acute test using the tube-dwelling amphipod, Ampelisca abdita. The continuous distribution function for sediment toxicity testing results are shown for Florida in Figure A-22. Most of the sediments proving significantly toxic to Ampelisca (control-corrected mortality > 20%) were located in Florida (7±13%) and Louisiana (1±2%) estuarine waters (Fig. A-23).

A.2.4 ALKANES AND ISOPRENOIDS

Alkanes and isoprenoids are contaminants associated primarily with the petroleum industry and uses of its products. None of the sediments in the province collected in 1993 are characterized by alkane concentrations in excess of 7000 ppb.

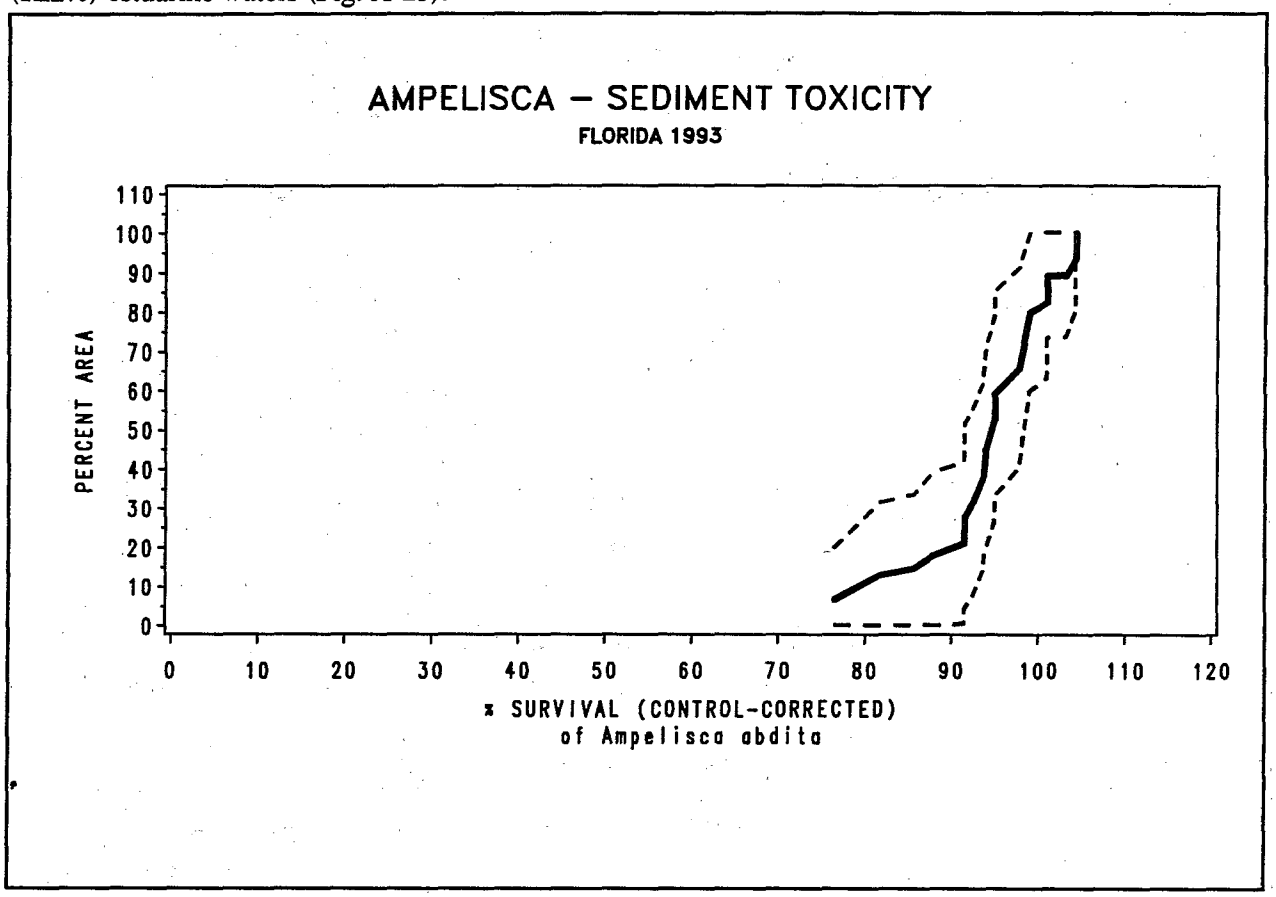


Figure A-22. Distribution of toxicity of estuarine sediments in Florida to amphipods (–) with 95% confidence intervals (--).

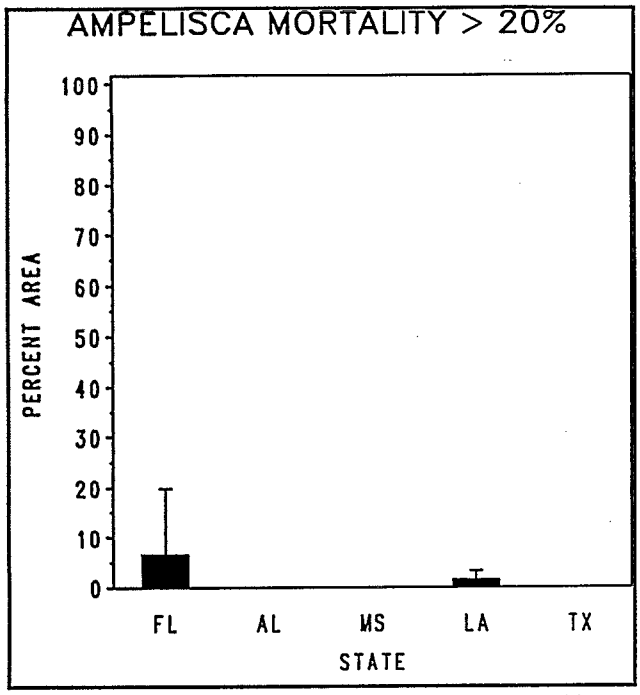


Figure A-23. Proportion of Gulf states' estuarine resources with toxicity to amphipods resulting in < 80% survival, with 95% confidence interval.

A.2.5 POLYNUCLEAR AROMATIC HYDROCARBONS

Forty-three individual polynuclear aromatic hydrocarbons (PAHs) were analyzed from collected Louisianian Province sediments. None of the sediments in the province collected in 1993 are characterized by PAH concentrations in excess of 4022 ppb.

A.2.6 POLYCHLORINATED BIPHENYLS

Twenty polychlorinated biphenyl (PCB) congeners were analyzed from the Louisianian Province sediments.Less than 1% of the sediments in Texas collected in 1993 had concentrations of PCB's in excess of 22.7 ppb.

A.2.7 TRIBUTYLTIN

Tributyltin (TBT), a compound found in antifouling paints until recently, was an effective and widespread means of protecting recreational and commercial craft from fouling organisms. The continuous distribution function of TBT in Texas is shown in Fig. A-24, ranging from 0 to 238 ppb. Using 1 ppb TBT as an indicator of the presence of TBT results in a more even distribution of TBT among the estuarine sediments of all the Gulf states (Fig. A-25).

A.2.8 PESTICIDES

Pesticides constitute a major portion of nonpoint source runoff from agricultural fields, suburban lawns, and golf courses. Twenty-four pesticides, including DDT and its derivatives, were analyzed from Louisianian Province sediments. Concentrations of chlordane in estuarine sediments were in excess of 0.5 ppb in Florida (8±15%), Louisiana (14±10%), and Texas (19±22%) (Fig. A-26). Dieldrin concentrations were > 0.02 ppb in sediments from all five gulf states: Alabama (89±5%), Louisiana (80±12%), Texas (48±27%), Florida (29±25%), and Mississippi (19±30%) (Fig. A-27). Endrin concentrations in excess of 0.02 ppb were also found in sediments collected at five states, Alabama (60±54%), Louisiana (23±13%), Texas (20±20%), Florida (12±16%), and Mississippi (4±5%) (Fig. A-28). There were also measurable concentrations of DDT > 1.0 ppb found in sediments collected from Louisiana (3±4%).

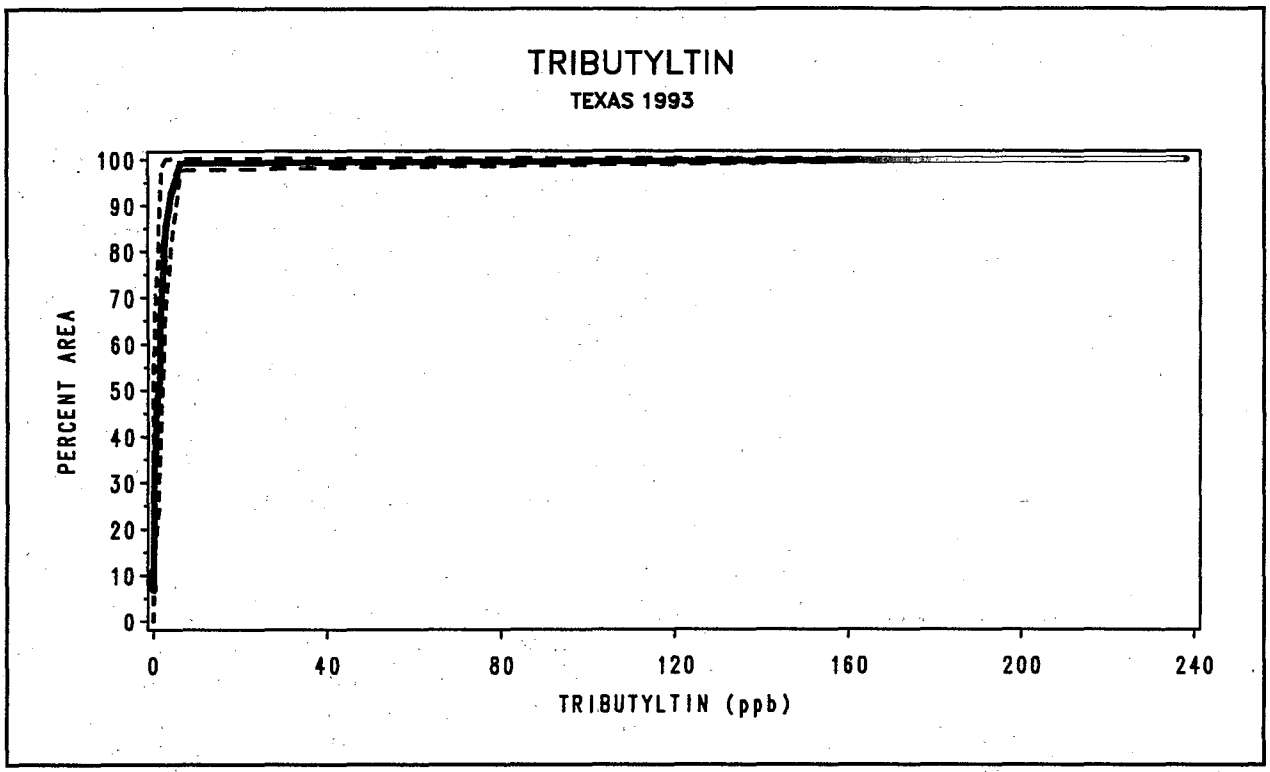


Figure A-24. Distribution of tributyltin in estuarine sediments of Texas (–) with 95% confidence intervals (--).

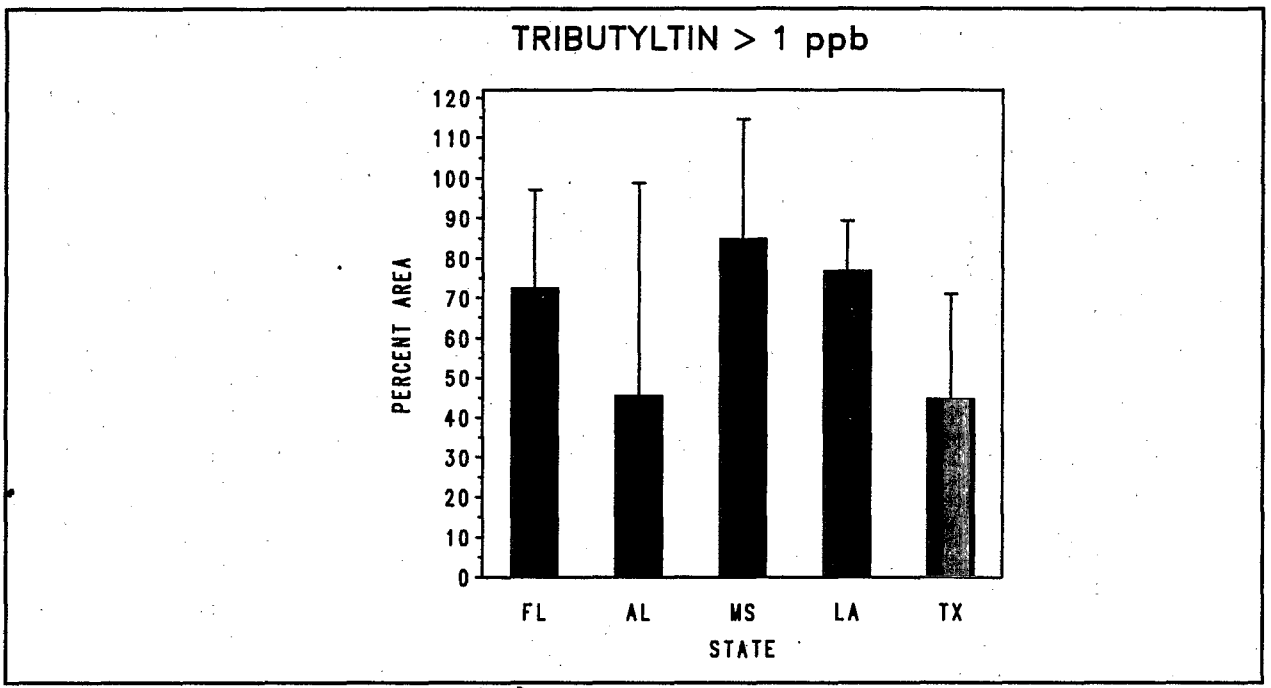


Figure A-25. Proportion of Gulf states estuarine sediments with TBT > 1 ppb, with 95% confidence interval.

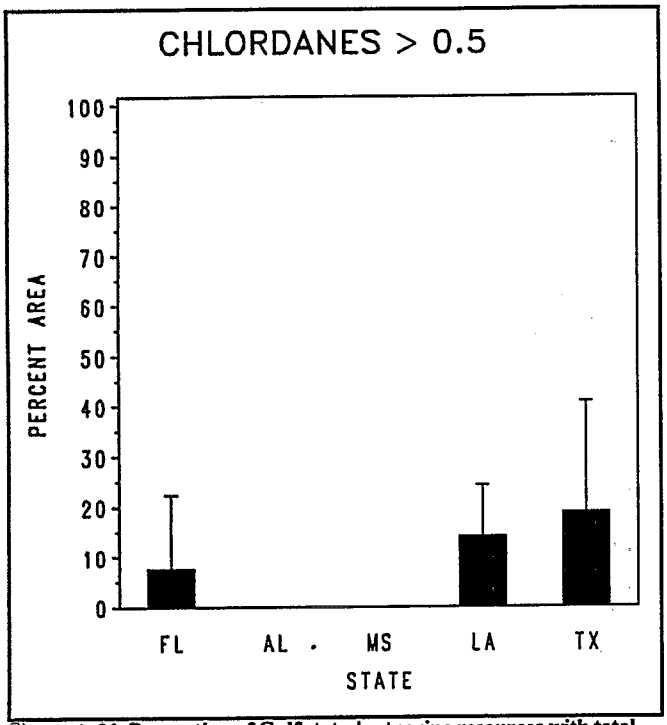


Figure A-26. Proportion of Gulf states' estuarine resources with total chlordanes > 0.5 ppb, with 95% confidence interval.

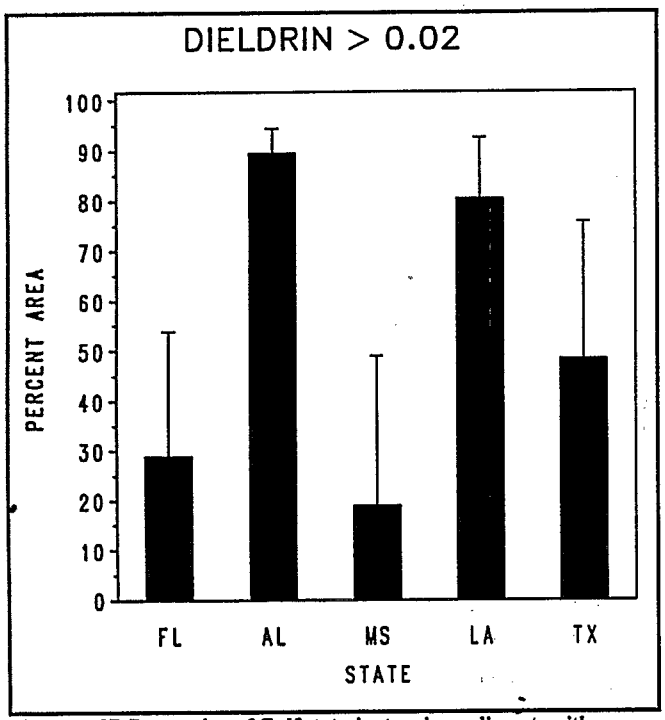


Figure A-27. Proportion of Gulf states' estuarine sediments with dieldrin > 0.02 ppb, with 95% confidence interval.

A.2.9 HEAVY METALS

Fifteen heavy metals were analyzed for the sediments collected in 1993. Examining the metal concentrations based on Long and Morgan criteria, several heavy metals exceeded the 10% criteria. The percentage of estuarine area in each state that exceeded the 10% Long and Morgan criteria for each analyzed metal is compared with the percentage of area in each state with heavy metal enrichment (Figs. A-29 to A-33).

A.3 CONFIDENCE INTERVALS FOR STATE-LEVEL ESTIMATES

Ninety-five percent confidence intervals (95%CI) were calculated for all parameters described in this section. The methods for these calculations were described in Summers *et al.* (1993b). Table A-1 provides these intervals for the major indicators for the proportion of the five Gulf States assessed as degraded for each parameter.

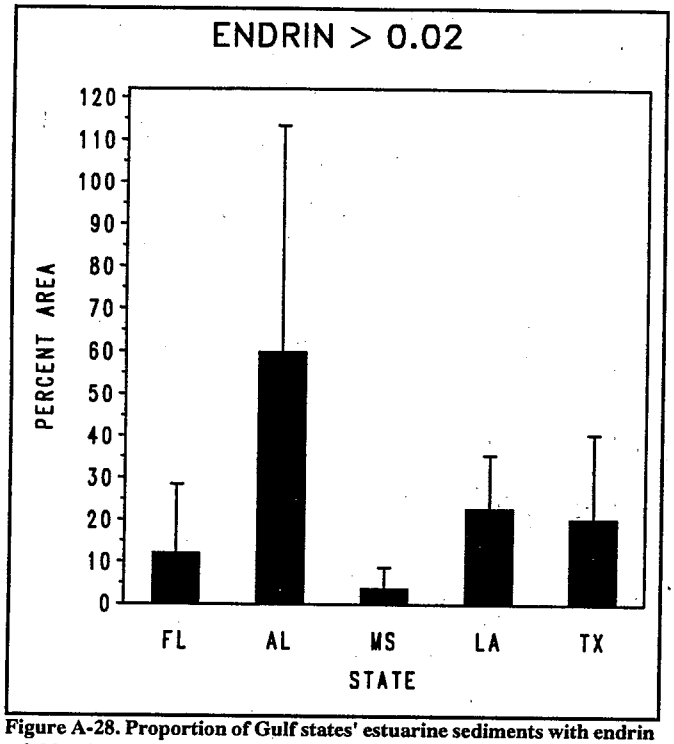


Figure A-28. Proportion of Gulf states' estuarine sediments with endrin > 0.02 ppb.

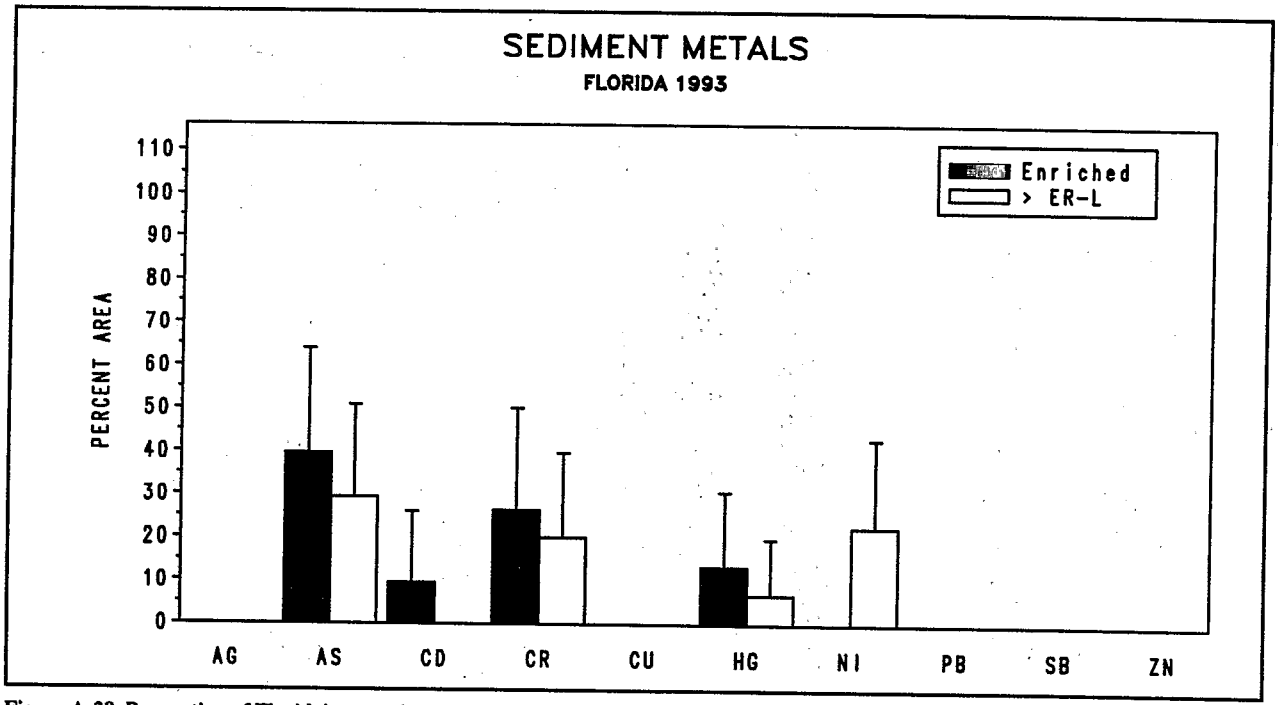


Figure A-29. Proportion of Florida's estuarine area with sediment metal concentrations > Long *et al* (1995) ER-L criteria or greater than expected based on aluminum concentrations, with 95% confidence interval.

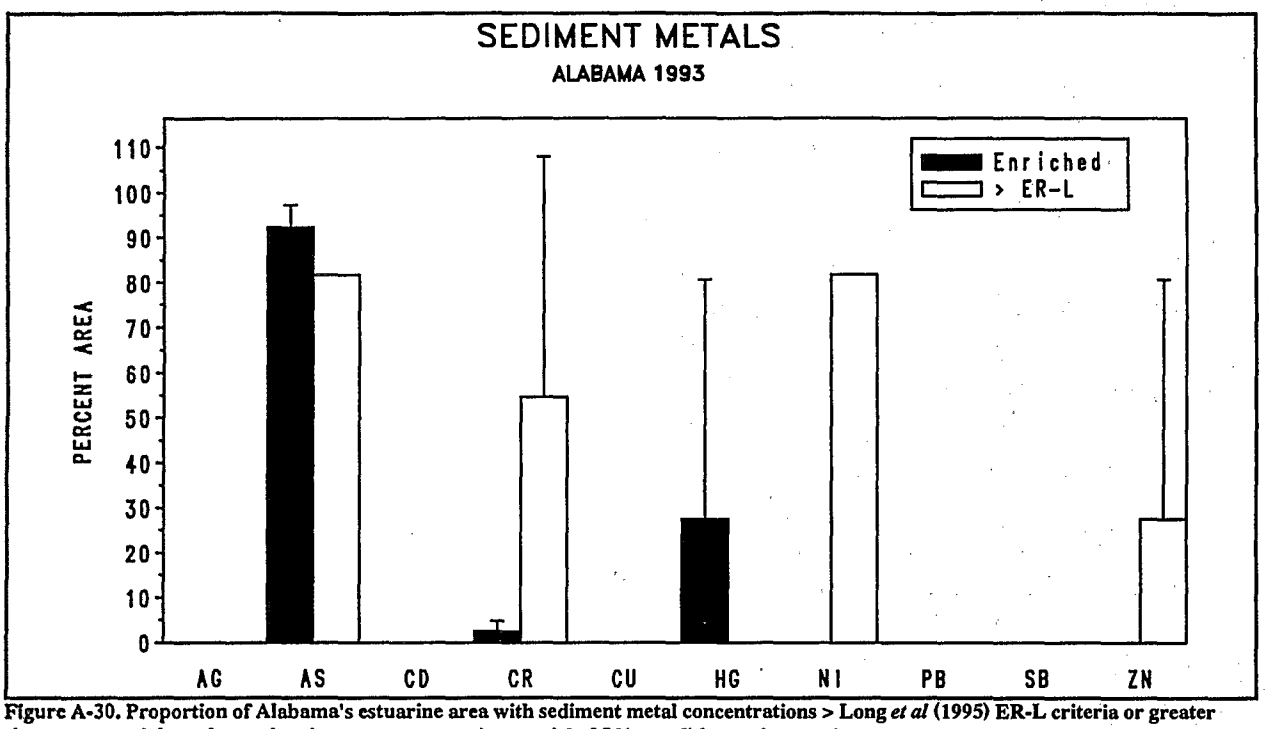


Figure A-30. Proportion of Alabama's estuarine area with sediment metal concentrations > Long *et al* (1995) ER-L criteria or greater than expected based on aluminum concentrations, with 95% confidence interval.

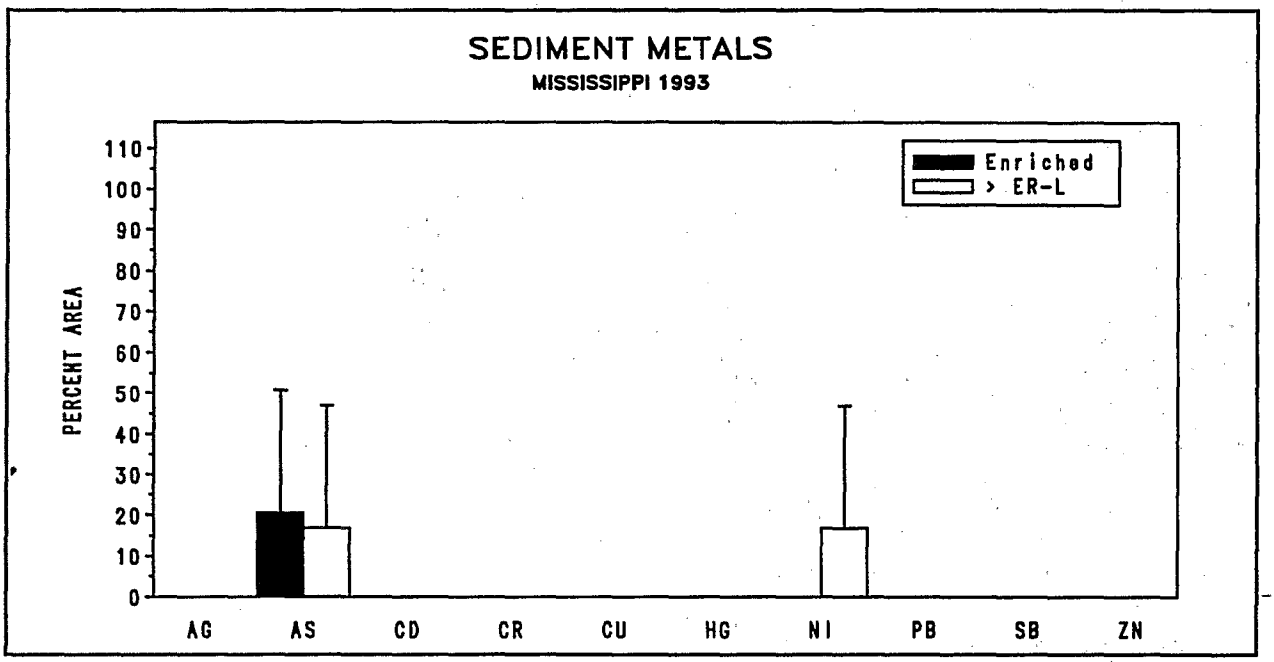


Figure A-31. Proportion of Mississippi's estuarine area with sediment metal concentrations > Long *et al* (1995) ER-L criteria or greater than expected based on aluminum concentrations, with 95% confidence interval.

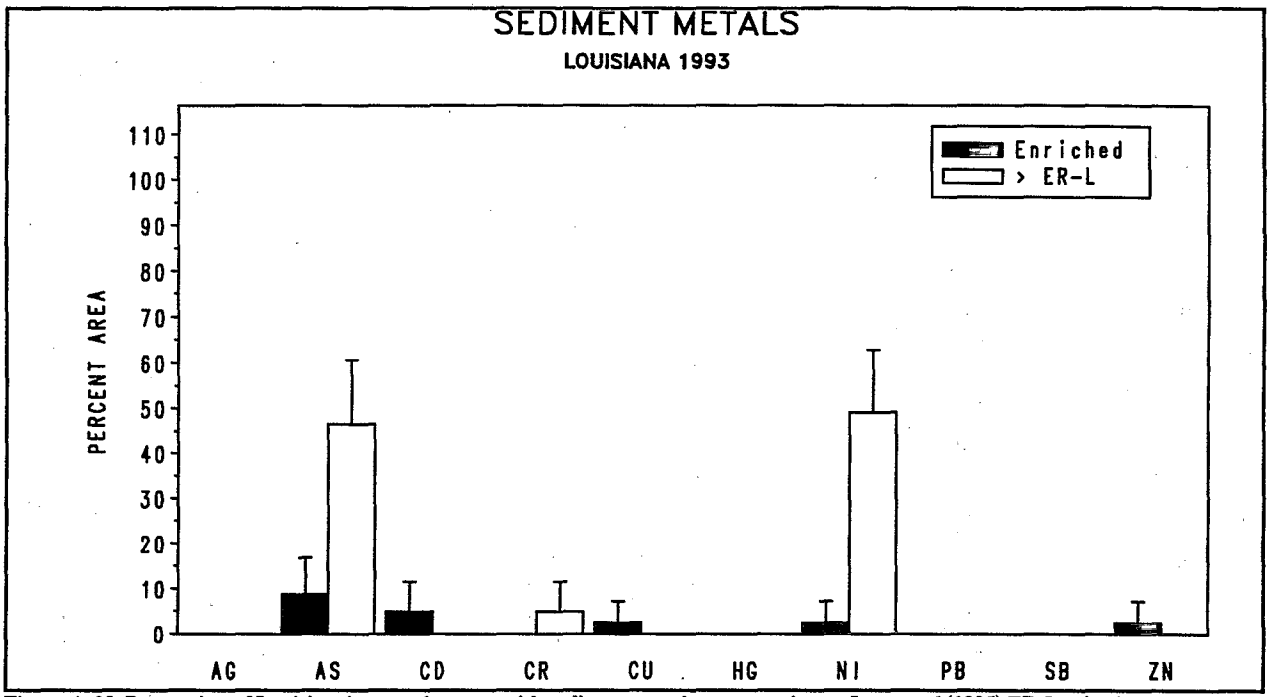


Figure A-32. Proportion of Louisiana's estuarine area with sediment metal concentrations > Long *et al* (1995) ER-L criteria or greater than expected based on aluminum concentrations, with 95% confidence interval.

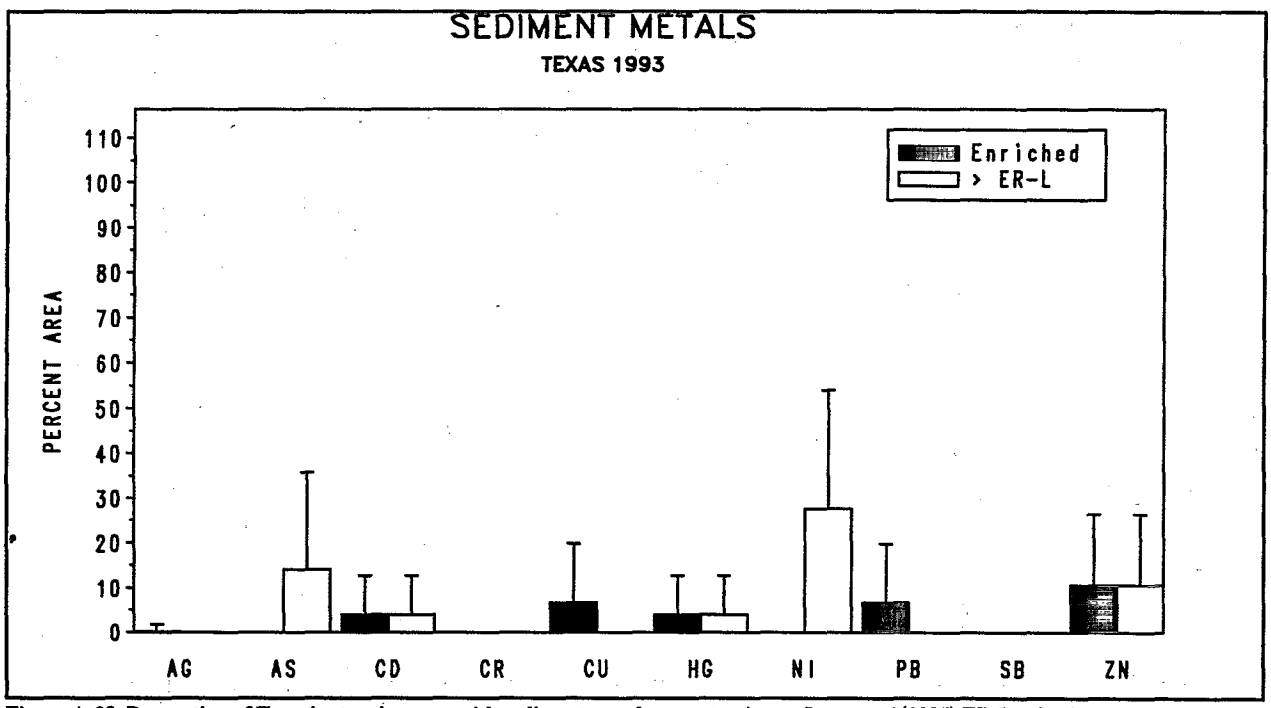


Figure A-33. Proportion of Texas' estuarine area with sediment metal concentrations > Long *et al* (1995) ER-L criteria or greater than expected based on aluminum concentrations, with 95% confidence interval.

Parameter	Florida	Alabama	Mississippi	Louisiana	Texas
N	20	7	7	38	21
Estuarine Condition	21(21)	18(3)	7(5)	59(14)	71(22)
Biotic Condition					
Benthic Index	17(18)	18(0)	7(5)	49(14)	66(26)
Abundance < 10	7(13)	5(4)	0(0)	7(8)2(4)	
# Species < 2	0(0)	5(4)	0(0)	0(0)	0(0)
# Species < 5	14(17)	32(54)	15(30)	12(10)	16(18)
Fish					
Abundance < 2	20(21)	0(0)	0(0)	10(9)	7(13)
Abundance 5	34(24)	5(4)	15(30)	19(12)	14(18)
# Species < 1	1(2)	0(0)	0(0)	2(5)	0(0)
# Species 2	14(16)	0(0)	0(0)	16(11)	7(13)
Fish Pathology	0(0)	0(0)	0(0)	15(11)	22(21)
Fish Contaminants[1]					
Shrimp					
Hg > FDA Limits	0(0)	0(0)	0(0)	0(0)	25(0)
Croaker					
All > FDA Limits	0(0)	0(0)	0(0)	0(0)	0(0)
Marine Catfish					
Hg > FDA Limits	0(0)	0(0)	0(0)	34(1)	0(0)
Others > FDA Limits	0(0)	0(0)	0(0)	0(0)	0(0)
Bottom DO[2] < 2 ppm	0(0)	33(54)	0(0)	12(10)	0(0)
Bottom DO[2] < 5 ppm	48(27)	71(53)	22(30)	31(14)	7(17)
Minimum DO < 2 ppm	20(20)	87(4)	15(30)	18(11)	9(18)
Sediment Toxicity	7(13)	0(0)	0(0)	1(2)	0(0)

[1] Percentage based on sample size rather than estuarine area
[2] Instantaneous dissolved oxygen measurements

Table A-1. Estimates of the proportion of the individual Gulf states experiencing the listed parameters and their associated 95% confidence intervals in parentheses (N = number of sampling sites).

Parameter	Florida	Alabama	Mississippi	Louisiana	Texas
N	20	7	7	38	21
Abiotic Condition					
Marine Debris3	3(12)	0(0)	0(0)	17(12)	12(19)
Water Clarity					
PAR < 10%	3(6)	8(5)	0(0)	30(10)	42(27)
PAR < 25%	28(22)	19(0)	24(30)	53(14)	81(23)
Silt-Clay Content					
< 20%	57(27)	16(2)	45(40)	5(7)	14(18)
> 80%	23(20)	55(53)	15(30)	46(14)	34(26)
Alkanes					
Total > 7000 ppb	0(0)	0(0)	0(0)	0(0)	0(0)
PAHs					
Total > 4022 ppb	0(0)	0(0)	0(0)	0(0)	0(0)
PCBs					
Total > 22.7 ppb	0(0)	0(0)	0(0)	0(0)	0(0)
Pesticides					
Chlordane > .5 ppb	8(15)	0(0)	30(19)	14(10)	19(22)
Dieldrin > .02 ppb	28(25)	89(5)	51(40)	80(12)	48(27)
Endrin > .02 ppb	12(16)	60(54)	4(5)	23(13)	20(20)
DDT > 1 ppb	0(0)	0(0)	0(0)	3(4)	0(0)
DDE > 2 ppb	0(0)	27(53)	0(0)	0(0)	0(0)
DDD > 2 ppb	0(0)	0(0)	0(0)	0(0)	0(0)
Metals					
Ag > 1 ppm	0(0)	0(0)	0(0)	0(0)	0(0)
As > 8.2 ppm	30(22)	82(0)	17(30)	46(14)	14(22)
Cd > 1.2 ppm	0(0)	0(0)	0(0)	0(0)	4(9)
Cr > 81 ppm	20(20)	55(53)	0(0)	5(7)	0(0)
Cu > 34 ppm	0(0)	0(0)	0(0)	0(0)	0(0)
Hg > .15 ppm	7(13)	0(0)	0(0)	0(0)	4(9)
Ni > 20.9 ppm	23(20)	82(0)	17(30)	49(14)	28(26)
Pb > 46.7 ppm	0(0)	0(0)	0(0)	0(0)	0(0)
Sb > 2 ppm	0(0)	0(0)	0(0)	0(0)	0(0)
Zn > 150 ppm	0(0)	27(53)	0(0)	0(0)	11(16)
Tributyltin					
TBT > 0 ppb	83(21)	89(5)	85(30)	93(7)	93(13)
TBT > 5 ppb	0(0)	27(53)	15(30)	9(8)	7(13)

[3] Estimate based on presence-absence, so 95% confidence intervals are not calculated.

Table A-1. (cont.) Estimates of the proportion of the individual Gulf states experiencing the listed parameters and their associated 95% confidence intervals in parentheses (N = number of sampling sites).

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