TOXICS CHARACTERIZATION REPORT

FOR

PERDIDO BAY,

ALABAMA AND FLORIDA

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ABSTRACT

Citizens, and State and Federal regulatory agencies, are concerned about chemical contamination of coastal ecosystems. In response to citizen interest in Perdido Bay, the U.S. Environmental Protection Agency (EPA) provided funding to the Fish and Wildlife Service (Service) to produce a status report about existing chemical conditions.

In addition to a review of existing reports and data, the Service conducted field work that included water, sediment and biotic chemical analyses, a ten-day toxicity test, a fish health assessment, and an evaluation of dioxin compounds.

A review of the most important chemical data bases for the Perdido Bay ecosystem reveals that Perdido Bay is generally free of toxic compounds. However, sediments in some discrete areas are contaminated. Contamination has been identified in Elevenmile Creek, Saufley Field Ditch, and Bayou Marcus. Detectable chemical contaminants have also been identified at one marina and in some locations within Perdido Bay. Contaminants of concern at some sediment sites include: mercury, silver and dioxin compounds.

Results of the field toxicity tests suggest that the water and sediments tested are not acutely toxic, but based on reduced feeding activity of the test organisms, there appears to be reduced water quality at some locations.

Samples of some species of fishes in the Perdido River contain undesirable concentrations of mercury. In the past, fish from Elevenmile Creek have contained quantities of dioxin. Fish collected from Elevenmile Creek, and analyzed within the last three years, contained minimal or non-detectable concentrations of dioxin compounds. These analytical data have resulted in the removal of the consumption advisory for fish taken from the Creek. Significant concentrations of dioxin have been found in two turtles collected from the Creek.

Recommendations for future research and for estuarine management include additional mercury and dioxin field work; evaluation of any environmental impacts related to agricultural chemicals; assessment of the need for, and practicality of, clean-up of silver-contaminated sediments at the mouth of Saufley Field ditch; and the continuation and acceleration of environmental management programs involving stormwater control, agricultural best management practices and state-of-the-art industrial and municipal effluent treatment.

KEY WORDS

Chemical contamination, mercury, silver, dioxin, Perdido Bay, Perdido River, Elevenmile Creek, Bayou Marcus, paper mill, agriculture, stormwater, silviculture, largemouth bass, white catfish, gafftopsail catfish, spiny softshell turtle.

PREFACE

The purpose of this report is to provide citizens, environmental managers and regulators, and other interested parties with a status report about chemical contaminants within the Perdido Bay watershed/estuarine ecosystem. The author has attempted to write, as often as possible, in a non-technical language in an attempt to inform readers about a fairly technical aspect of environmental management.

Part One focuses on identification of chemical contaminant problems. Also included in Part One are recommendations for management of the Perdido Bay ecosystem.

Part Two of the report, Basic Information for Citizens, provides important information for those readers that are unfamiliar with the subject of chemical contamination in the environment. Environmental managers, scientists, Federal and State regulators and others with background knowledge in the field of chemical contaminants can begin their review of the report with Part Two. However, those unfamiliar with that subject are firmly, but respectfully, encourage to read Part One first.

Part Three deals with potential sources of contaminants within the Perdido Bay Drainage Basin including permitted point sources discharges, and non-point sources including urban stormwater runoff, agricultural, silviculture, and superfund hazardous waste sites.

Part Four is a review of existing chemical contaminants information and data bases for the Perdido Bay area and includes information about the most important studies conducted and reports written. Some review of the extent of field work conducted to date, is also presented.

Finally, Part Five is a review of the work conducted within the Perdido Bay ecosystem by the U.S. Fish and Wildlife Service. It includes some water quality information and fairly extensive sediment, bioassay and biota information.

All references are identified in the Literature Cited section that follows Part Five. Supporting documents including data, quality control information, and operational procedures for some activities are provided in Appendices.

This report is dedicated to the owners and stewards of Perdido Bay - all United States citizens.

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PART ONE - REPORT SUMMARY AND RECOMMENDATIONS FOR MANAGEMENT

REPORT SUMMARY

This document provides a current status report on chemical contaminants potentially affecting the Perdido Bay ecosystem. However, because of the size of the system, and the limitations placed on chemical contaminant studies, this assessment should not be considered a comprehensive, conclusive evaluation. Several areas of contaminant research within the system require further investigation. In some cases, relative to the problems identified, specific restorative actions may be advisable.

The surveys and assessments completed by various agencies and other parties have provided a much better picture of the conditions and status of chemical contaminants within the Perdido Bay ecosystem. The objective of this report was to review and examine all available information with the aim of identifying problems, if any existed. To that end, the following observations are now made. These observations pertain to certain toxic chemicals or chemical groups, or to situations where not enough information is available to draw conclusions.

I. Dioxin and Dioxin-like Compounds

Many parties are currently awaiting publication of the forthcoming re-assessment of dioxin to be released by the EPA, probably in early 1994. Until that time, definitive interpretations of certain forms of dioxin data are not possible. However, the levels of dioxin within the Elevenmile Creek environment and its biota, coupled with the lack of information about the possible distribution of dioxin compounds within the sediments of Perdido Bay, leave managers and regulators with a situation that requires:

1) better information related to the risks, both human and wildlife, that exist under the environmental concentrations that are documented; and 2) more field data related to the areal distribution and concentration levels for the parts of the Perdido Bay ecosystem that could have been affected, but have not been tested.

The results of several studies reveal that dioxin is present within the Elevenmile Creek area and the biota living there. Sediments in the backwater portions of the Creek have significant dioxin contamination. No sediment data exists for Perdido Bay proper. Minimal concentrations of both dioxin and furan compounds have been detected in fish taken from Elevenmile Creek. The only other animal tested for dioxin contamination is a species of turtle collected from the Creek. The two individuals that were analyzed had relatively high concentrations of dioxin compounds (17 and 35 ppt, dioxin toxicity equivalents) in muscle tissue samples.

II. Mercury

At this time, mercury contamination is not new to Florida. It has been recognized as a form of contamination existing in several parts of the State. Quite a bit of information exists about contemporary and historic sources of mercury. Florida Department of Health and Rehabilitative Services consumption advisories have been released for various areas of the State, including the Perdido River (Florida HRS 1993). Mercury is known to have been a component in slimicides used by the paper mill industries many years ago. In the United States, mercury slimicides in wood pulp were banned in 1965 from paper products that would come into contact with food (D'Itri et al., 1977).

Mercury has been documented in the sediments of Elevenmile Creek at concentrations ranging from 0.26 to 1.1 parts per million (ppm), dry weight. However, wet weight values in fish from the Creek did not exceed consumption advisories. Gafftopsail catfish, a free-ranging marine species collected in the Bay, did have muscle tissue concentrations exceeding Florida's lower consumption advisory. Largemouth bass collected in the Perdido River had concentrations exceeding the lower advisory level of 0.5 ppm, wet weight. For this reason, a consumption advisory has been issued for the Perdido River, and consumption of largemouth bass from the River should be limited to one meal per week (Florida HRS 1993). Information on sources of mercury for the Perdido River and for the gafftopsail catfish is lacking.

III. Silver

Silver concentrations (4.0 ppm, dry weight) in sediments at the mouth of Saufley Field ditch exceeded the Probable Effects Level sediment quality guideline (2.5 ppm), a concentration at which biological effects would nearly always be expected. However, if the silver contamination is in a fairly small area, and an upstream source can be documented and controlled, cleanup may be relatively simple.

IV. Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) currently appear to be a minimal problem within the Bay area. None of the sites sampled by the Service had concentrations that exceeded sediment quality guidelines. However, future implementation of control measures may be necessary at those sites that currently have somewhat high concentrations.

V. Chemical Contaminants For Which Data Is Lacking.

In the section of this report addressing agricultural runoff, Table 2 summarizes the use of the newer agricultural pesticides in the Perdido Estuarine Drainage Area. To date, no field data exists related to any accumulation in, or impacts to, biota for these chemicals. Therefore, it is impossible to state whether or not use of these agricultural chemicals is having an effect upon resources within the Perdido Bay ecosystem.

RECOMMENDATIONS FOR MANAGEMENT OF PERDIDO BAY

Review of the existing data and assays (for the chemicals that have been evaluated) indicates that contamination is not a widespread problem, but that localized problems of a minimal to moderate nature do exist. The following recommendations for future management of the ecosystem are offered for consideration:

1. Further evaluation of dioxin in Elevenmile Creek, including: a) additional upstream sediment sampling; and b) additional investigation of potential dioxin impacts to resident biota living in or adjacent to the Creek. Appropriate restoration of the Creek, if warranted.

2. Additional survey of the sediments of the Bay to assess the degree of dioxin distribution beyond the mouth of Elevenmile Creek. Appropriate actions, as necessary, based on the data obtained.

3. Continued monitoring of fishes of the Perdido River for mercury, as deemed appropriate by the Florida Department of Health and Rehabilitative Services and the Florida Game and Fresh Water Fish Commission. Encourage additional research

that will define the sources of mercury within the ecosystem. Evaluate any risks and impacts associated with the mercury in the sediments of Elevenmile Creek.

4. Evaluation of the extent of silver contamination at the mouth of Saufley Field ditch. Identification and elimination of the source of contamination. Restoration actions at the site, if appropriate.

5. Consideration of future source control measures at the locations identified as having somewhat high PAH sediment concentrations.

6. Design and implementation of an agricultural chemicals field assessment survey to provide an evaluation of the potential impacts of these chemicals. Continued use of EPA Best Management Practices throughout the watershed, with a survey to evaluate the extent to which these practices are being applied.

7. Development of a Perdido Bay ecosystem management plan for the control of current and future point and non-point source discharges, including a provision to evaluate and monitor cumulative impacts to the ecosystem. The Plan should incorporate the best approaches of both the Alabama and Florida programs. Implementation of the plan, as soon as possible, throughout the ecosystem.

PART TWO - BASIC INFORMATION FOR CITIZENS

INTRODUCTION

This report characterizes the current environmental condition of Perdido Bay with regard to toxic compounds or chemical contaminants. Therefore, included in the report is an overview of the sources and/or potential sources of contaminants, a survey of the presently existing chemical contaminant data available from all sources, and an evaluation (involving both quantitative statements and qualitative observations and judgments) about the current condition of the bay. Finally, the report includes: a) identification of specific contaminant problems; and, b) recommendations related to management, further study, and correction and/or restoration activities necessary to conserve and enhance the resources and environmental quality of the Perdido Bay estuarine system.

Perdido Bay encompasses an area of about 50 square miles between Alabama and Florida with the State line running approximately down the centerline of the bay (Figure 1). The drainage basin covers 1,205 square miles and encompasses parts of Baldwin and Escambia Counties, Alabama and western Escambia County, Florida. The Perdido River is the largest single source of freshwater entering the bay. Numerous tributary streams in the upper basin drain hilly country, forming the Perdido River and its two major tributaries, the Styx and Blackwater Rivers. Other tributaries of the bay include Elevenmile Creek, Eight Mile Creek, and Bayou Marcus Creek in Florida, and Soldier Creek and Palmetto Creek in Alabama. The Gulf Intracoastal Waterway passes through lower Perdido Bay, connecting it to estuaries in Alabama to the west and

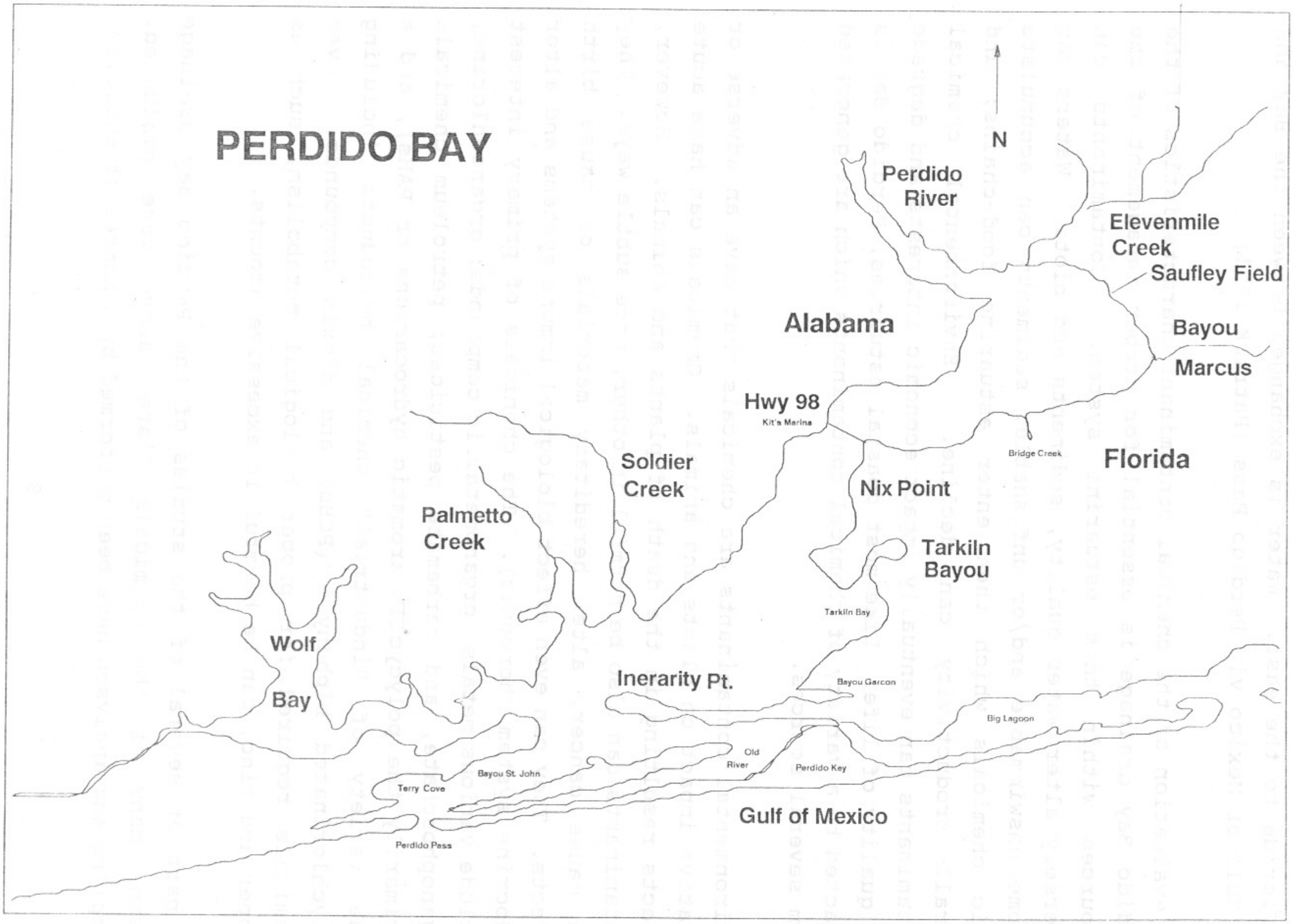

Figure 1. Perdido Bay, Alabama/Florida

in Florida to the east. Water is exchanged between the Bay and the Gulf of Mexico via Perdido Pass (Patrick 1991).

The evaluation of the chemical contaminant characteristics of the Perdido Bay drainage is essential for proper management of the resources within this estuarine system. Contaminants can adversely alter water quality, sediments and biota. Waters can become unswimmable and/or unfishable; sediments can accumulate toxic chemicals which then enter estuarine food-chains; and overall productivity can decline. Environmental chemical contaminants can eventually impact economic interests and degrade the quality of life. Like most coastal estuaries, Perdido Bay is impacted by a variety of chemical contaminants which are generated from several sources.

Environmental contaminants are chemicals that have an adverse or negative impact on plants and animals. Chemicals can have acute effects resulting in the death of plants and animals. However, contaminants can also be harmful in other, more subtle ways. They can cause cancer, alter hereditary materials or cause birth defects. They can even effect biological immune systems and alter endocrine system (hormones). The chemicals of primary interest include various metals; organometallic compounds; organochlorine, organophosphate, and carbamate pesticides; petroleum chemicals (primarily the polycyclic aromatic hydrocarbons or PAHs), and a wide variety of "industrial" chemical byproducts including polychlorinated biphenyls (PCBs) and dioxin compounds. Even chemicals required for proper biological metabolism, such as copper and zinc, can be harmful in excessive amounts.

As part of several of the studies of the Perdido Bay drainage basin, many of the chemicals listed above were evaluated. Sampling and analyses have been performed by a number of entities, including the U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (Service), Florida Department of Environmental Regulation (FDER) [now the Florida Department of Environmental Protection (FDEP)], Alabama Department of Environmental Management (ADEM), Environmental Planning and Analysis, Inc.(EPAI), Tierra Consulting (TC) and Champion International Corporation (CI).

THE LIMITATIONS OF CHEMICAL ANALYSES AND CHEMICAL DATA

It is important to be aware of the limitations inherent in each attempt to evaluate chemical contaminants in a natural system as complex as a coastal estuary. Therefore, some general remarks related to these limitations are appropriate.

I. Water Samples

Water samples require the greatest care when collected and handled in the field. Water samples can easily become unintentionally tainted (contaminated) from careless handling, unclean sample containers, etc. Furthermore, water samples sometimes do not provide useful information about environmental contamination because: a) many chemicals are "hydrophobic" (water-fearing) and move quickly out of the water column into sediments, plant material, or animal tissues and; (b) the amounts of chemicals that can dissolve in water are often very minute, requiring extremely sensitive laboratory procedures to detect these small quantities.

II. Sediment Samples

Sediment samples require less care in handling, but still must be handled properly to avoid accidently contaminating them. However, to be able to compare sediment sample information obtained by different collectors (Federal agencies, State agencies, universities, etc.), some degree of uniformity must exist. One cannot compare sediment contamination between samples unless basic information about each sample is available. Information that is required about the sediment sample includes: the percentage of sand; silt; clay; and total organic carbon (TOC). For instance, a sample with 80 percent sand cannot be directly compared with a sample containing 20 percent sand, because each sample's capacity to accumulate chemicals is different. Furthermore, particularly for metals, just knowing the "total amount" of a metal present is not too informative.

Metals are found in different parts or "locations" of the sediment. The metal could be dissolved in the water found between the grains of sand, silt, or clay (the "pore" water phase); or associated with silts, clays, or the organic phase (primarily composed of dead, decaying plant material). The metal may be in a variety of chemical forms or even associated with an organic (carbon-structured) compound. Both the "location" and the "form" of a metal in a sediment sample are very important because these characteristics define how "available" that metal contaminant is to living organisms (called "bioavailability"). When metals are associated with the pore water or the organic carbon fraction of a sediment they are usually much more available to living organisms than when they are associated with other parts of the sediment. Finally, metals are a natural part of sediments. It is important for environmental managers to be able to define how much metal has been introduced by human activities versus how much occurs naturally.

III. Biological Samples

Samples collected from living organisms also have limitations. First, if fish were collected , the entire fish might be ground up and analyzed. This would provide information about what might be available to some animal that ate the entire fish; but it would provide little information about "human exposure" if only the fillet of the fish were eaten. Second, chemical contaminants in animals and fish also tend to "partition" or accumulate in particular parts of the body. Metals, for example, often accumulate in the liver; but mercury accumulates more in the muscle tissue, particularly in fish. The question then becomes, how should samples of fish or other animals be analyzed? If effects on reproductive capacity are a concern, then the ripe but unfertilized eggs of the female may be the tissue to submit for analysis. However, if human health is the concern, then the "edible" portion of the animal should be analyzed. Third, only particular species of fish or other animals yield reliable information about a localized area, such as Perdido Bay. If the question revolves around a "local" source of pollution, then fish that are largely seasonal or migratory, such as bluefish or Spanish mackerel, would not provide a clear picture of impacts to local biota. Thus, resident fishes such as largemouth bass in the river, or spotted seatrout in the bay, would be better because they do not move great distances. Still, any fish can move away from, or nearer, a pollution source.

IV. Cost of Chemical Analyses

Depending on the type of analysis performed, costs can be as high as $2,000 per sample in order to detect and meet quality control standards. Each group of chemicals (metals, organochlorine pesticides, petroleum compounds) can cost several hundred dollars, per sample. Analysis for dioxin alone can exceed $2,000 per sample which makes this kind of analysis particularly expensive. The types of samples that are often shipped for direct analysis include: water samples; sediments and/or soils; and tissues from animals, including a variety of invertebrates (shrimp, crabs, etc.); fishes, amphibians, reptiles, birds and mammals.

OTHER METHODS USED TO OBTAIN CHEMICAL CONTAMINANT INFORMATION

Chemical analysis of a variety of things (water, sediments/soils, or living organisms) often provides useful information. However, chemical analysis can be very expensive, and the limitations of such information should be understood. There are other ways to gain valuable information about chemical impacts to the Perdido Bay system. These approaches, while usually less expensive, are still equally important in providing significant information for managers and decision makers. Therefore, the Fish and Wildlife Service and other agencies often employ one or more of the following techniques.

I. Toxicity Tests

A toxicity test is a test or series of tests during which particular living organisms are exposed to both suspected contaminated (test) materials and uncontaminated (control) materials. The animals used in a toxicity test may be very small invertebrates, and/or newly hatched or juvenile fishes. The test materials could be water or sediments suspected of containing chemical contaminants. Several criteria are used to measure the effect of the chemicals in the test materials on the organisms being tested. The usual unit of measure is death of a significant percentage of the test animals (mortality); however, 1) inhibited or reduced growth, 2) reduction in normal feeding rate, or 3) changes in an animal's behavior are other indicators of adverse effects. Comparisons are made between the animal responses being measured in the test materials and in the uncontaminated control materials. Toxicity tests are run for set periods of time such as, 72 hours, 96 hours, 5 days, or 10 days. The toxicity test described later in this report was run for ten days. Toxicity tests are very labor-intensive, but do not usually require an inordinate amount of funding for chemical analysis.

II. Visual Inspections of Animals for Abnormalities

Chemical contaminants in the environment often manifest their presence by affecting wildlife with birth defects, tumors, lesions, and abnormal tissue and cell growth. Examination of samples of animals collected from suspected contamination sites can provide relatively inexpensive clues to environmental problems. The Service, working jointly with the EPA, collected fishes from Perdido Bay, Perdido River, and Elevenmile Creek. These fishes were carefully examined for abnormalities. The results of that survey are provided later in this report.

GENERIC SOURCES OF CHEMICAL CONTAMINANTS

Management of the sources of chemical contaminants is primarily the responsibility of three agencies, the U.S. Environmental Protection Agency (EPA), the Alabama Department of Environmental Management (ADEM) and the Florida Department of Environmental Protection (FDEP). The EPA regulates and manages these sources through the Federal Clean Water Act (33 U.S.C. §§ 1251-1387). In addition, in Florida, it is EPA that regulates the issuance of National Pollutant Discharge Elimination System permits for point source discharges. ADEM operates under provisions found in the Alabama Water Pollution Control Act (AWPCA), Code of Alabama (COA) 1975, §§ 22-22-1 through 22-22-14, as amended, and the Alabama Environmental Management Act, Code Of Alabama 1975 §§ 22-22A-1 through 22-22A-16, as amended. FDEP management authority for contaminant sources is found in several State laws, including: the Florida Environmental Control Act (Chapter 403 Florida Statutes), and the Florida Clean Outdoor Air Law. In general, there are several common sources from which chemical contaminants are introduced into rivers, creeks and coastal bays. They include the following:

I. Point Sources

Many contaminants enter the environment from a specific point of discharge, usually released from the end of a pipe. The chemicals are part of a watery effluent that flows from an industry, municipal treatment plant, business or small residential sewage treatment facility. These point source discharges require a National Pollutant Discharge Elimination System (NPDES) permit under Section 402 of the Federal Clean Water Act (33 U.S.C. §§ 1251-1387). The program is regulated by ADEM in Alabama and by EPA for Florida.

II. Urban Stormwater Runoff

Rainwater washes a multitude of chemicals into coastal waters. From developed areas these chemicals wash off lawns, streets, parking lots, roofs and all other impervious surfaces. The runoff may contain herbicides, insecticides, oils and greases, metals, and industrial chemicals. If stormwater treatment structures are not constructed to capture and retain these contaminants, they usually end up in natural waters such as rivers or bays.

III. Agricultural Runoff

Wet-weather runoff from cropland, pastures, feedlots and other agricultural facilities can introduce organic materials, fertilizers, and pesticides into rivers and bays. The farmland of a drainage basin, if not properly managed, could be a significant contributor of contaminant materials.

IV. Silvicultural Runoff

Activities associated with forest management can also introduce a variety of chemicals into the drainage basin. Introduction of chemicals is often accelerated by ditching and draining activities. Several of the compounds used in forest management practices are not associated with other agricultural activities. Chemicals carried by stormwater runoff may be transported from forest lands to open waters. On the average, land alteration and application of chemicals is not as intensive on forest lands as it is on farm lands. However, in northwest Florida large tracts of land are used for silviculture.

V. Airborne Sources of Contaminants

Many chemicals originate at points far removed from an area of concern. The incineration processes associated with many industries, such as coal-fired power plants and municipal solid waste facilities, introduce chemicals into the atmosphere that may be carried long distances before finally settling onto land or water. Polluted air can result in significant impacts to the environment, particularly to plant communities (Heck and Anderson 1980).

Provisions of the Clean Air Act (42 U.S.C §§ 7401 et seq.) are enforced and regulated by the Environmental Protection Agency.

PART THREE - POTENTIAL SOURCES OF CHEMICALS WITHIN THE PERDIDO BAY DRAINAGE BASIN

POINT SOURCES

Point source discharges (usually effluent flowing out of a pipe) can contribute a variety of chemical compounds to coastal waters. The quality of these effluents is regulated under the Federal Clean Water Act. Section 402 of the Act establishes the National Pollutant Discharge Elimination System (NPDES) permit program. Through this program, discharges are evaluated, monitored and regulated. In the State of Florida, NPDES permits are issued by the U.S. Environmental Protection Agency's Regional Office in Atlanta, Georgia. In the State of Alabama, the NPDES program has been turned over to the State's Department of Environmental Management.

There are several point source discharges that may affect Perdido Bay. Most of these discharges are not direct releases into the Bay, but instead are discharged to rivers, creeks, bayous and other backwaters that feed the Bay. Although each discharge into an estuary is evaluated individually, rarely during permit review is the "cumulative impact" of many discharges assessed. However, it is important that an assessment of cumulative impacts be made, and that Perdido Bay's capacity to assimilate compounds and pollutants from many point source discharges be determined. There is a limit to the pollutant load that an estuary can accept. If the limit is exceeded, the estuary will suffer some detrimental environmental impacts. An estuary management plan needs to consider the combined effect of all present and future discharges.

An inventory was taken of the currently permitted outfalls in order to understand the status of point source discharges affecting the Bay. The inventory includes information about discharges that are no longer in operation. These "historic" discharges are included because impacts from these sources (degraded sediments, etc.) may still be affecting the environmental quality of the Bay. A brief description of each point source discharge is provided below based on information provided by U.S. EPA and ADEM.

I. Industrial Operations

The four industries that discharge within the Perdido Bay drainage basin are Champion International Corporation, Sunbelt Chemicals, Inc., Masland Carpets, Inc., and Arizona Chemical Company.

A) Champion International Corporation - Permit No. FL0002526

The Champion paper mill, located at Cantonment, Florida contributes the greatest volume of industrial effluent to the Bay. The primary product of the mill is high-quality bleached paper. The company's long term average industrial effluent discharge is 20.13 million gallons per day (MGD); with a maximum 30-day average of 22.33 MGD; and a daily maximum of 38.93 MGD. The permit expires August 31, 1995. Some of the parameters regulated in this permit include biochemical oxygen demand (BOD), total suspended solids (TSS), ammonia, color, chlorinated organics, dioxin, and zinc. The point of effluent discharge is at the head of Elevenmile Creek, approximately 11 miles from the mouth. The Creek empties directly into Perdido Bay.

B) <u>Sunbelt Chemicals, Inc. Permit No. AL0053091</u>

The Sunbelt Chemical plant is located at Atmore, Alabama and discharges treated washwater, storm water and non-contact cooling water into an unnamed branch of Brushy Creek which flows into the Perdido River. The point of discharge is over 50 river miles above the head of Perdido Bay. The permit limits pH, total suspended solids (TSS), total residual chlorine and sulfides. The permit expires on July 31, 1996.

C) <u>Masland Carpets, Inc. - Permit No. AL0021997.</u>

This company is located at Atmore, Alabama. As part of the company's industrial process, the effluent from the plant (1 MGD daily maximum discharge) contains quantities of BOD, chemical oxygen demand (COD), TSS, phenol, chromium, sulfide and ammonia. The permit requires these parameters and chemicals be measured, as well as flow, pH, and dissolved oxygen. At a point over 50 river miles from Perdido Bay, the effluent is discharged into Boggy Branch which flows into Brushy Creek, and then into the Perdido River. The permit expires September 30, 1998.

D) <u>Plasmine Technology, Inc., Permit No. AL0000841.</u>

This company is located in Bay Minette, Alabama. Effluent from the plant is discharged into Hollinger Creek which flows into the Styx River. The Styx River flows into the Perdido River. The point of discharge for this facility is over 45 river miles from the head of Perdido Bay. The NPDES permit for this facility sets discharge limitations for pH, BOD, TSS, oil and grease, ammonia, total kjeldahl nitrogen and dissolved oxygen. The permit expires October 14, 1997.

II. Municipal Facilities

There are five active sewage treatment plants (STP) in the basin. In addition, there are two locations where plants were formerly operated. Environmental impacts could still exist downstream of the discharge points of these presently closed facilities.

A) The Utility Board of the City of Atmore. Permit No. AL0049557.

The Utility Board operates a treatment plant that discharges into Boggy Branch at a point in excess of 50 river miles from Perdido Bay. The effluent parameters regulated by permit include flow, BOD, TSS, pH, dissolved oxygen and residual chlorine. The permit expires on October 12, 1994.

B) The Utilities Board of the City of Bay Minette. Permit No. AL0049867, as modified on December 30, 1991.

The Utilities Board operates the Harry Still Sr. Wastewater Treatment Plant with a design flow of 2.0 MGD. Effluent from the plant is discharged into Hollinger Creek at a point over 45 river miles from Perdido Bay. Parameters regulated by permit include flow, BOD, TSS, nitrogen (NH_3-N), pH, and dissolved oxygen. Bioassay toxicity tests are required on a quarterly basis, and must exhibit less than ten percent mortality of test organisms. The permit for this facility was issued on July 16, 1990, modified on December 30, 1991, and expires July 31, 1995.

C) The City of Robertsdale. Permit No. AL0042838.

The City of Robertsdale, Alabama operates a sewage treatment facility with a permitted discharge of 0.55 MGD to Rock Creek. Rock Creek flows into the Blackwater River which ultimately flows into the Perdido River. The point of discharge for this facility is over 26 river miles from the head of Perdido Bay. Characteristics regulated by permit include flow, BOD, TSS, nitrogen (NH3-N), pH, dissolved oxygen and residual chlorine. The permit expires March 31, 1997.

D) The Escambia County Utilities Authority. Permit No. FL0031801.

The Utilities Authority operates the Avondale Wastewater Treatment Plant at Pensacola, Florida. Effluent from the plant is discharged into Bayou Marcus Creek approximately one mile upstream of Perdido Bay. The design capacity of the plant is 2 MGD. The NPDES permit regulates BOD, TSS, fecal coliform, pH, chlorine, total nitrogen, and total kjeldahl nitrogen. In addition, biomonitoring in the form of a series of toxicity tests is required. The permit expires January 31, 1994.

E) The Escambia County Utilities Authority. Permit No. FL0038504.

The Utilities Authority also operates the Cantonment Wastewater Treatment Plant. The point of discharge is at the head of Elevenmile Creek. The parameters limited by permit include BOD, TSS, total Kjeldahl nitrogen, fecal coliform bacteria, total residual chlorine, dissolved oxygen and pH. The permit expires October 31, 1994.

F) <u>The City of Pensacola. CLOSED FACILITY. Permit No. FL0020168.</u>

The City formerly operated the Lincoln Park STP. Effluent from the plant was discharged into Eight Mile Creek which flows into Elevenmile Creek, and then into Perdido Bay. The plant has been closed for several years and any remaining effects that may exist in Eight Mile Creek have not been evaluated.

G) <u>The City of Pensacola. CLOSED FACILITY. Permit No. FL0020150.</u>

The City also operated the Montclair STP. Effluent from this plant was discharged into Bayou Marcus. The design capacity was 0.5 MGD. BOD, TSS, fecal coliform, pH and chlorine were regulated. The plant has been closed for several years and any remaining effects that may exist in Bayou Marcus, related to this facility, have not been evaluated.

III. Commercial Activities

The "commercial," "business," and "residential" point sources discharging into the Perdido Bay drainage basin include an Interstate Highway welcome center, a boys' ranch, a country club, and a mobile home park.

A) <u>Alabama Highway Department. Permit No. AL0024911.</u>

The Department operates a welcome center at Loxley on Interstate 10. Effluent from rest facilities is discharged into the Perdido River approximately 14 river miles from Perdido Bay. Flow is not greater than 0.014 MGD. The permit sets limits for BOD, TSS, ammonia as nitrogen, pH and chlorine residue. The permit expires September 30, 1997.

B) The Alabama Sheriff's Boys Ranch Southwest. Permit No. AL0058220.

The Ranch at Summerdale discharges not greater than 0.005 MGD of domestic waste effluent into an unnamed tributary which flows into Negro Creek, then to the Blackwater River, and ultimately into the Perdido River. The point of discharge is in excess of 22 river miles from the Bay. BOD, TSS, NH3, and pH are regulated and monitored. The permit expires May 30, 1994.

C) Perdido Bay Partnership. Permit No. FL0025411.

The Partnership operates a facility for the Perdido Bay Resort and Country Club. The point of discharge is into unnamed lakes on the grounds of the facility. The effluent may not directly affect Bayou Garcon, an arm of Perdido Bay adjacent to the Country Club. The permit expires October 31, 1994.

D) Silver Lake Mobile Home Estates. Permit No. FL0037028.

The Estates operate a small treatment plant that discharges treated sanitary wastewater into Eight Mile Creek. Parameters regulated include BOD_5, TSS, total Kjeldahl nitrogen, fecal coliform, dissolved oxygen, pH and total residual chlorine. The permit expires August 31, 1996.

IV. Military Facilities

The U.S. Navy has two point source discharges within the Perdido Bay drainage basin.

A) Pensacola Naval Air Station - Saufley Field. Permit No. FL0021041.

The Station maintains a sewage treatment plant that discharges into Perdido Bay via a quarter mile long drainage ditch. Parameters regulated include BOD, TSS, fecal coliform, and pH. The permit has expired and is currently being re-evaluated by EPA for re-issuance.

B) U.S. Navy, Naval Education Training Program. Permit No. FL0037435.

The Program had a discharge into Perdido Bay. However, the discharge facility is no longer operating and this is an inactive permit (Leedy, personal communication).

NON-POINT SOURCES

Non-point sources are defined as stormwater runoff not associated with a specific point of origin; that is, these sources do not flow out of the end of a pipe or other precise point of discharge. Therefore, they are not regulated under the Federal NPDES permit program. However, both Alabama and Florida have programs addressing the management of non-point sources. Non-point sources include stormwater runoff from natural lands (forests, swamps, etc.), managed lands (silviculture, agriculture, etc.) and from urban/developed areas (streets, lawns, parking lots, roof tops, etc.). The cumulative impacts associated with the long-term loading of non-point source runoff into Perdido Bay has not been evaluated and needs to be considered for proper estuarine management. Indications are that non-point sources, particularly large influxes of freshwater and sediment loads, may play an important role in the environmental character of Perdido Bay.

I. Urban Stormwater Runoff

An assessment of urban development within the Perdido Bay drainage basin is provided in a companion volume for this study which characterizes land uses associated with the study area (Patrick 1991). Urban development has historically been a minor component of land use in the Perdido River and Bay area. However, there are some developed areas within the basin that may be contributing measurable amounts of chemical contaminants to the Perdido Bay system. Table 1 identifies the most significant areas of urban development within the Perdido Bay drainage basin.

Table 1. Primary Sites for Urban Runoff Management Within the Perdido Bay Drainage Basin, 1992.

COUNTY	PRIMARY SOURCE	RECEIVING WATERS
Escambia Co., FL	West Pensacola	Bayou Marcus
Escambia Co., FL	Cedarbrook Subdiv.	Elevenmile Creek
Escambia Co., FL	Copper Forest Estates	Elevenmile Creek
Escambia Co., FL	Forest Hills Dev.	Elevenmile Creek
Escambia Co., FL	Lake Estelle Subdiv.	Eight Mile Creek
Escambia Co., FL	Residential Dev.	Bayou Garcon
Baldwin Co., AL	Residential Dev.	Palmetto Creek/ Spring Branch
Baldwin Co., AL	Residential Dev.	Soldiers Creek
Baldwin Co., AL	Town of Lillian	Perdido Bay
Baldwin Co., AL	Ono Island Res. Dev.	Bayou St.John/ Old River
Baldwin Co., AL	City of Bay Minette	Hollinger Creek
Escambia Co., AL	City of Atmore	Brushy Creek

Although urban development is not extensive within the Perdido Basin, assessment and monitoring of urban runoff should be an integral component of any bay management program. Assessment should begin with those sources identified above.

Programs already exist within the States of Alabama and Florida to accomplish urban runoff management. Alabama has an effective Nonpoint Source Management Program (Alabama Department of Environmental Management 1989). The State of Florida also effectively manages urban runoff under stormwater legislation (Florida Statutes) through the State's Department of Environmental Protection and the Water Management Districts. Management of urban runoff will become increasingly important in the future as growth continues around Perdido Bay.

II. Agricultural Runoff

Patrick (1991) has discussed agricultural land use within the Perdido Basin. In that report she noted that erosion is a major issue related to proper management of Basin streams and the Bay. A variety of chemicals are associated with routine crop management. Such chemicals include herbicides, insecticides, fungicides, fumigants, growth regulators, repellents and rodenticides. Many of these compounds can be transported by wind or stormwater runoff away from farmlands and into ditches, tributaries, rivers and eventually into estuaries such as Perdido Bay. Drainage basins experiencing significant amounts of erosion are more likely to have chemicals transported off of application sites than areas where erosion is minimal. These chemicals can be transported dissolved in water, attached to organic particles, or attached to silt and/or clay particles.

Chemicals transported off farmlands can have a negative impact on fish and wildlife resources. Some of the things that must be considered in an attempt to evaluate any agricultural chemical impact to a system such as Perdido Bay include the following:

A) The chemical nature and toxicity of the particular compound.

B) The compound's persistence in the environment.

C) The gross amount of the compound introduced into the study per unit of time (annually, monthly, etc).

D) The sensitivity of particular organisms to the compounds of interest.

E) The most sensitive "life stages" of the organisms.

The best assessment of agricultural pesticide use within the Perdido Bay drainage area has been developed by the National Oceanic and Atmospheric Administration (NOAA). Table 2 provides usage information for the 25 pesticides believed by NOAA to be most important for crop management in the drainage area. The use of each particular pesticide is equated to the most toxic pesticide in the study (i.e., "normalized" to phorate) using acute toxicity information (LC_{50} for fish) to calculate a Coefficient of Relative Toxicity (CRT). The CRT was then multiplied by the total amount applied of each pesticide to produce a "normalized" toxicity. In this way, both the total amount used and a pesticides particular toxicity are considered to compare the complete affect of each pesticide on at least one group of wildlife, in this case estuarine and freshwater fishes (see Pait, et al., 1989).

Table 2 reveals that chlorothalonil, phorate, parathion, and trifluralin are the chemicals to evaluate first to determine the degree of adverse environmental impacts related to agricultural pesticides.

In NOAA's agricultural pesticide use assessment for estuarine drainage areas (EDAs), 23 sites were evaluated along the Gulf of Mexico. A total for normalized toxicity was calculated for each EDA just as was done for Perdido Bay (see Table 2, lower right).

Table 2. Use of pesticides in the Perdido Estuarine Drainage Area (1982) with toxicity normalized values generated using phorate LC50 data for estuarine and freshwater fish. From Pait et al., 1989.

Pesticide Code #	Pesticide (active ingredient)	Usage (lbs/year)	Normalized Toxicity
Herbicides			
1	Acifluorfen	8,176	<1
2	Alachlor	54,903	16
3	Atrazine	40,485	26
4	Bensulide	66	<1
5	Cyanazine	220	<1
6	2,4-D	10,524	<1
7	Dinoseb	8,854	71
8	Fluometuron	116	<1
9	Metolachlor	12,089	<1
10	Trifluralin	13,983	113
11	Vernolate	2,53	1
Insecticides			
12	Carbaryl	7,974	6
13	Carbofuran	7,548	49
14	Diazinon	207	<1
15	Disulfotan	2,171	5
16	Malathion	74	<1
17	Methamidophos	805	<1
18	Methyl Parathion	6,671	5
19	Parathion	5,783	208
20	Phorate	275	275
Fungicides			
21	Captafol	929	37
22	Chlorothalonil	7,820	317
23	Metiram	23	<1
24	PCNB	40	<1
Nematocides			
25	Ethoprop	1,060	7
TOTAL		193,378	1,147

The total for Perdido Bay can be compared to the normalized toxicity totals for the other sites. The EDA with the greatest normalized toxicity total was Laguna Madre, Texas. It ranked number 1 with a total of 28,383. St. Andrew Bay, Florida ranked number 23 with a total of 80. By comparison, Perdido Bay ranked number 17 with its total for normalized toxicity being 1,147.

This is simply a comparison of relative loading of agricultural pesticides between Gulf EDAs. It does not define the relationship that exists between pesticide loading of an estuary and such factors as the overall size of the estuary, the estuaries' hydrologic ability to flush or assimilate toxic pesticides, or the particular plant and animal species in the estuary and their specific sensitivities to pesticides.

III. Silviculture Operations

Forestry operations, particularly commercial operations, date back to at least 1860 when Willis J. Milner built a sawmill on the Perdido River just above the mouth of the Styx River. The industry centered around logging of the native, virgin timber of the area until that resource was exhausted. By the 1920s, an increasing demand for pulpwood stimulated land owners to begin to plant pine and other species over large tracts (Livingston 1989).

Today, approximately 77 percent of the Perdido Basin (928 of 1,205 square miles) is devoted to some form of silviculture. Commercial timber land is owned primarily by International Paper Company, Scott Paper Company, Champion International Corporation and Dupont (Patrick 1991). Champion's Western Florida Timberlands Region alone manages 313,000 acres in northwest Florida and another 225,000 acres in southern Alabama. The trees managed include loblolly pine, slash pine, longleaf pine and sand pine (Westmark 1992).

Modern management of lands used to grow trees for paper production is a complex process. Such management involves incorporation of many "best management practices" which reduce soil erosion and help control pollution of streams and lakes. Some of the forest management techniques also require the use of a variety of chemicals, including fertilizers, herbicides, and various insecticides. Use of chemicals (particularly insecticides) on forest lands is not as intensive as it is on agricultural lands. However, considering that 77 percent of the basin is in silviculture activity, an evaluation of pesticide usage and potential impacts to Perdido Bay resources is warranted. No in-depth evaluations or documentation of any specific chemical problems resulting from silviculture activities within the Perdido Basin are available (Patrick 1991). Some of the common herbicides and insecticides used in forestry management in the southeast U.S. are presented in Tables 3 and 4.

Table 3. Common herbicides used in southern forests, their persistence, solubility and toxicities.

Herbicide	Soil[1] Half-Life (days)	Solubility[2] (mg/L) (H_2O)	Toxicity[1] LD50[3] (mg/kg)	Toxicity[1] LC50[4] (mg/L)
Atrazine	70	33	5,100	24
2,4-D	<10	900	300	1.38
2,4-DP	<10	710	580	1.38
Dicamba	<14	6,500	2,900	>999
Fosamine	<10	1,790	24.400	670
Glyphosate	<60	15,700	5,600	120
Hexazinone	<30	33,000	1,690	370
Picloram	<90	430	8,200	26.5
Simazine	<30	3.5	5,000	16
Triclopyr	<50	430	713	148

[1] Neary, 1985. [2] Humburg, 1989. [3] LD50 for mammals.
[4] LC50 for bluegill sunfish.

Table 4. Common insecticides used in southern forests, their persistence, solubilities and toxicities.				
Insecticide	Soil[1] Half-Life (days)	Solubility[2] (mg/L) (H_2O)	Toxicity[2] LD50 (mg/kg)	Toxicity[2] LC50 (mg/L)
Acephate	3	650,000	700-945[3]	>1000[4]
Azinphosmethyl	<80	28	10[3]	.003[5]
Carbofuran	60	n.i.[6]	11[3]	0.24[4]
Fenvalerate	50	n.i.[6]	451[3]	0.00042[4]
Malathion	6	145	2800[3]	.070-.335[4]

1 Neary, 1985, based on average literature values.
2 Sine, 1992, Farm Chemicals Handbook - '92.
3 rat, oral 4 bluegill 5 rainbow trout
6 nearly insoluble in water.

Several of the herbicides listed in Table 3 are sometimes combined as formulations under brand names. For instance, "Access" is a formulation involving a picloram ester and a triclopyr ester. Other herbicides used by the forest industry have the trade names: Accord, Accord CR (glyphosate); Arsenal (imazapyr); Banvel 720, CST (dicamba); Dichlorprop (2,4-DP); Fusilade 2000 (fluazifop-butyl); Garlon 3A, 4 (triclopyr); Oust (sulfometuron methyl); Poast (sethoxydim), Pronone 5G, 10G (hexazinone), Roundup (isopropylamine salt of glyphosate); Tordon 101 Mixture, K, RTU and 101R (picloram); Velpar (hexazinone); and Weedone (2,4-DP ester) (Miller et al., 1988; Sine, 1992). The herbicides used have generally low toxicities to fish and other aquatic life if applied according to label directions. Herbicide use, however, is significant because paper companies try to realize the greatest yield of trees and maximum production of their final products. The herbicides are usually applied after harvest (clear cutting) to assure the pine nursery areas are basically free from competition of other woody plants.

Very little application of insecticides (Table 4) occurs in commercial forests affecting the Perdido Bay drainage. The southern pine beetle can be a problem in some southern forests, but primarily that insect is a concern in Texas and not now in this area (Beitzel, personnel communication).

IV. Superfund Hazardous Waste Sites

The problem of improper disposal of chemical wastes was recognized acutely with the chemical contamination of property in the Love Canal area of Niagara Falls, New York in 1978. Hazardous wastes have been created and accumulated across the nation, primarily as a byproduct of the synthetic organic chemical revolution of post-World War II America (McClain 1991). In a response to the recognition of the existence of literally hundreds of chemical hazardous waste sites across the United States the U.S. Congress, in 1980, passed Public Law 96-510, the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), more commonly known as the Superfund Act. The Act was modified and strengthened in 1986 by passage of Public Law 99-499; the Superfund Amendments and Reauthorization Act of 1986 (SARA).

Improperly disposed chemicals and other toxic degradable products pose a threat to the environment primarily because they do not remain confined to the original site of disposal. Usually such materials were disposed of in earthen pits and covered; but sometimes they were simply dumped on the land. Even wastes in containers eventually escaped into the environment as the containers ruptured or corroded. Chemicals move off of an original disposal site in a number of ways. Some chemicals are aromatic and volatile, enter the atmosphere, and are transported by wind, or returned to the ground, off-site, by rain. Often chemicals are simply washed off site by stormwater, and enter ditches, tributaries, creeks, rivers, lakes or estuaries. As a result both surface soil contamination and aquatic sediment contamination can occur. Transport of hazardous chemicals can also occur by movement through geologic aquifers (groundwater) resulting in the contamination of wells and surface waters. Once hazardous waste chemicals are released into the environment they pose a threat to fish, wildlife and man. Exposure through air, soil, sediment or water can result in bioaccumulation of many of these toxic chemicals. The other major route of exposure for wildlife is through the food chain, where biomagnification of the chemicals can occur.

In view of the potential threat posed by Superfund waste sites, they are evaluated as part of the survey of chemical contaminant sources within the Perdido Bay drainage area. Compounds from such sites could find their way into surface water and eventually the Bay. Three sites exist in the study area, and they are briefly described below.

A. Beulah Landfill Site

According to the EPA, the Beulah Landfill is located in Escambia County, Florida, approximately eight (8) miles northwest of Pensacola, Florida and 4,000 feet north of U.S. Highway 90. The site encompasses approximately 80 acres, divided roughly in half by Coffee Creek. The Creek runs eastward into Elevenmile Creek, which flows south along the eastern boundary of the site and eventually empties into Perdido Bay.

The site was operated by Escambia County as a landfill from 1966 until June 1984. At various times during its active life, it received municipal trash, septic sludge and industrial wastes. From February 1, 1980 until June 1984, the site was operated under a consent order with the State of Florida Department of Pollution Control, which limited the types of waste which could be accepted.

The north side of the landfill was used primarily for the disposal of municipal trash and possibly other unknown wastes, while the south side received industrial wastes as well as municipal trash. These wastes were deposited in excavated cells, which varied in depth from 4 feet to 35 feet below the land surface.

The analytical results of groundwater, surface water, sludge and soil samples indicate the presence of zinc, copper, chlordane, penta-chlorophenol, phenol, PCB 1260 and several polynuclear aromatic compounds, including anthracene, fluoranthene, naphthalene and pyrene. The wastes disposed at the site potentially affect the nearby surface water bodies, Coffee Creek and Elevenmile Creek, and the shallow groundwater system, the local sand and gravel aquifer (EPA 1991).

EPA has completed the Final Remedial Investigation. That evaluation resulted in a determination of acceptable risk, i.e. that the chemical contaminants present were in small enough concentrations that no threat to the welfare of humans or wildlife existed. Therefore, EPA released a "no action" determination in their Record of Decision (ROD). The landfill will be closed under Chapter 17-701 of the Florida Statutes. Some monitoring of the site will continue, the details of which will be worked out between the EPA and the Florida Department of Environmental Protection (Best, personal communication).

B. Dubose Oil Products Company Site

The Dubose Oil Products Company site is situated on about 20 acres of sloping land in Escambia County, Florida. The site is two miles west of the town of Cantonment. From a maximum elevation of 165 feet above mean sea level (MSL), the site slopes downhill to the north to an elevation of 80 feet above MSL. Jacks Branch receives runoff from the site. The Branch flows into the Perdido River, which in turn flows into Perdido Bay.

Dubose Oil was operated by Mr. Earl Dubose from January 1979 to November 1981. The company dealt in waste storage, treatment, recycling and disposal of waste oils, petroleum refining wastes, wood treatment processing waste, paint waste, spent solvents, and spent iron/steel pickle liquors. The separated wastes were sold to asphalt companies.

Water sampling by the Florida Department of Environmental Regulation (FDER) in 1982 revealed that contamination existed in on-site springs and seeps, as well as in a pond on site. In October of 1983, O.H. Materials (under contract to FDER) conducted a site assessment study that discovered buried drums, soil and sediment contamination, and surface water contamination. The FDER conducted a hydrogeologic investigation in early 1985 and concluded that the local perched water table aquifer was contaminated with low levels of chlorinated hydrocarbons (Engineering-Science, Inc. 1991).

Emergency response action was undertaken by FDER between November 1984 and May 1985. A containment vault was excavated in the basin of what was formerly a pond on the site. The vault was provided with a 36 mil liner, filled with contaminated soils and covered with a 30 mil liner.

The Environmental Protection Agency commenced a Remedial Investigation in February of 1988. Analyses of environmental samples collected during that investigation indicated that the extent of contamination was relatively limited. Trace metals were not found in concentrations that greatly exceeded "background" concentrations of uncontaminated soils or waters. Some low concentrations of pesticides were found in some soil samples. Only one sample of 84 contained PCBs at detectable levels. The contaminants that were detected at the site included; a) 5 volatile aromatic compounds, b) 17 polynuclear aromatic compounds, 15 phenolic compounds, and 21 halogenated non-aromatic volatile compounds.

The evaluation and cleanup work at Dubose Oil is being continued by the EPA in cooperation with the FDER.

As of November, 1993 the actions defined in EPA's final Record of Decision are being implemented, and the construction phase of clean-up is underway. The work is being performed by the Waytech Corporation and includes several components. One of the most critical to cleanup is the biotreatment facility. This facility will be used to "clean" contaminated soils currently held in an earthen vault. Bacterial activity in the soils will digest the contaminants and clean the soils. Treatment of the soils will take approximately two years. After this work is completed, the water from ponds on site will also be treated if necessary. However, analyses have shown that the pond water contains very few chemical contaminants. After the pond water meets EPA specifications, it will be drained into Jacks Branch. Ultimately the vault and pond excavations will be backfilled with clean soils, capped and the facility closed. Monitoring wells will be installed to allow the area to be sampled periodically, to assure that the clean-up operation was successful (Fite, personal communication).

C. Pioneer Sand Site

The Pioneer Sand Site is located near the town of Belleview, approximately five miles northwest of the City of Pensacola. The northeast shoreline of Perdido Bay is approximately two miles from the site. A Site Investigation under the direction of FDER, and funded by EPA through the Superfund, was conducted during the months of December 1984 and February of 1985 by Woodward-Clyde Consultants. The results of sampling and analyses during that study revealed that the following chemicals were detected at the site in significant concentrations: cadmium, chromium, copper, lead, mercury, nickel, thallium and zinc; volatile organic compounds; phenolics; polynuclear aromatic hydrocarbons; phthalates; and polychlorinated biphenyls (Woodward-Clyde 1985).

The Pioneer Sand site is underlain by a shallow aquifer (20-50 feet in depth) and a deeper sand aquifer from 80 to 250 feet in depth. Flow direction in the shallow aquifer is toward the south at approximately 1 to 2 feet per day. Flow in the deeper aquifer is toward the west at less than one foot per day. Well testing, on and off the site, indicated that the contaminants dumped at the site had remained in place and did not, at that time, pose an immediate danger away from the disposal area

(Woodward-Clyde 1985). There are no surface water connections between the Pioneer Sand site and Perdido Bay.

Additional, extensive work was undertaken by EPA from 1985 through 1993. The results of those investigations revealed that there had been no ground water or wetland contamination caused by the site. EPA undertook remedial actions including 1) solidification of the sludge pond, 2) placement of a synthetic cap over the site, and 3) construction of a leachate collection trench. Completion of these actions led to a close of remediation activities. In February 1993, the site was deleted from the Federal National Priorities List of superfund sites. Ground water monitoring will continue on a quarterly basis for about one more year, then monitoring will occur on a semi-annual basis (for up to 20 years), to assure public and environmental safety (Goldberg, personal communication).

PART FOUR - CHEMICAL CONTAMINANT REPORTS, SURVEYS AND DATABASES

Described below, in Section I, are the primary existing or draft (soon to be published) documents that provide information about chemical contaminants and their presence in water, sediments and biota of the Perdido Bay ecosystem. Information about each document or report has been included in the form of an abstract or annotation. If an abstract existed for the report, it has been reproduced below. If an abstract was not available, an annotation or summary was created using information gleaned directly from the introduction and conclusions section of the reports. Every effort has been made to quote directly from a report whenever possible. In Section II below, information is provided about sampling stations in the Bay for the most comprehensive studies and types and numbers of samples. Individual permit activities and small project data are not included.

I. Available Printed Documents

A. Multi-Agency Reports:

1. Report: The Perdido Bay Interstate Project. A Report on Physical and Chemical Processes Affecting the Management of Perdido Bay. 1991. Alabama Department of Environmental Management (ADEM) and Florida Department of Environmental Regulation (FDER) (see Schropp et al., 1991).

The Florida Department of Environmental Regulation and Alabama Department of Environmental Management initiated this study in response to increasing public and agency concern over the future of Perdido Bay.

Objectives of this study were to describe physical and chemical processes affecting dissolved and particulate nutrient and suspended solid transport in the Perdido River basin and the fate of these materials in Perdido

Bay. Sediments were also analyzed for metals and organic compounds.

Components of the study included:

a) Water movement (streamflow, estuarine circulation)
b) Water chemistry (river chemistry, estuarine chemistry) and
c) Sediment chemistry.

Because of the limited resources available for the Interstate Project and general perceptions regarding conditions in the upper part of the bay, information gathered during this study provides a better basis for evaluating environmental conditions in the upper bay (north of Highway 98) than in the lower bay.

The results of this study show that Perdido Bay receives nutrients from anthropogenic sources, dominated during this study by materials delivered by Elevenmile Creek. The Styx and Blackwater Rivers and Bayou Marcus Creek also show evidence of anthropogenic contributions of nutrients. A substantial portion of carbon delivered to the estuary is trapped in the upper bay. The results also show that physical conditions in Perdido Bay, controlled by the natural forces of wind, streamflow, and tide, are such that stratification and hypoxia occur during a major portion of the year. Summer and early fall months are critical periods when maximum natural stresses (hypoxia) are imposed on the bay and its biological communities. Oxidation of carbon trapped in the bay can aggravate seasonal hypoxia.

The results of sediment studies indicate that, at present, Perdido Bay does not suffer from acute toxic contamination. There is evidence of some contamination from urban runoff, although contaminants have not reached levels encountered in other, more developed parts of Alabama and Florida.

B. State of Alabama

1. **Report: Brushy Creek/Boggy Branch Water Quality Survey. 1986.** See Alabama Department of Environmental Management, 1986.

The purpose of this report is to document the ambient water quality of Brushy Creek and Boggy Branch in the vicinity of the Atmore POTW (NPDES permit no. AL0021183) prior to construction and operation of new facilities (NPDES permit no. AL0049557) and to document any water quality changes resulting from the up-grading of the POTW.

The headwaters of Brushy Creek and its tributaries originate in Escambia County, Alabama, and flow into the Perdido-Escambia River system in Escambia County, Florida. Brushy Creek has a drainage area of approximately 20 square miles, with a 10-year 7-day low flow of 8.5 cfs and an average flow of 42 cfs.

Brushy Creek proper appears to be meeting its water use classification of fish and wildlife as indicated by the water quality samples collected.

Boggy Branch, from its confluence with Brushy Creek to Station B-4, continues to appear polluted due to the new Atmore WWTP's poor performance and the continuance of C.H. Masland's (now Masland Carpets, Inc.) discharge.

Improvements in the water quality of Boggy Branch resulting from construction of the new POTW, if any, would probably be negated by Masland's discharge and would be difficult to demonstrate due to the close proximity of the two discharges.

C. State of Florida

1. **Report: Study IV. Perdido Bay Drainage Survey.** North Florida Streams Research Project. 1990. See Florida Game and Fresh Water Fish Commission, 1990.

ABSTRACT

A total of 72 fish species, 41 from the Perdido River only, 22 from both the Perdido and Elevenmile Creek and 9 from Elevenmile Creek only, were collected during the study period. Five species collected have not previously been recorded from the Perdido River. Ichthyofauna and water quality of the Perdido River is comparable to other Florida panhandle streams. However, fish and water quality samples taken in Elevenmile Creek show it to be a highly degraded system. Factors documented in this study indicating a degraded habitat in Elevenmile Creek included: the absence of pollution intolerant species, the presence of common carp and white catfish, and the preponderance of only a few species by both numbers and weight.

2. Report: Prediction of Water Quality at Perdido Bay. Florida Department of Environmental Regulation. See Taylor, R. Bruce, 1991.

This report describes the first steps taken towards developing a simple predictive model which could be used to examine the gross movement of selected waterborne substances through the Bay and resulting long-term changes in water quality. The model is derived from the combination of empirical relationships rooted in the data collected as a part of the Perdido Bay Interstate Project, and fundamental principles of estuarine dynamics and the conservation of mass.

Because of its [Perdido Bay] unique configuration, predictions for user specified conditions of wind, tide, and freshwater inflow over extended periods of interest (e.g., years) can be generated within minutes on standard 386 PC hardware. For example, the model could be used to predict changes that would occur in the Bay if pulp mill effluent was diverted from Elevenmile Creek into land-based disposal.

The simple model of Perdido Bay presented here offers a new and potentially powerful tool for the effective management of coastal regions and resources. Its primary attraction is embodied in a unique synthesis of an extensive data base with a simple set of predictive formulations which are derived from first principles. The result is a simple, easy to use predictive analytical tool which is capable of describing the changes in Bay water quality and the gross movement of water and waterborne substances throughout the Bay in response to actual or imposed conditions of source loading, tide, wind and freshwater inflows.

In its present form the model examines the transport and mixing of any conservative constituent introduced to the Bay. However, with relatively little effort it could be modified to examine the movement and concentration levels of specific water quality parameters such as dissolved and particulate nutrients, dissolved oxygen, and suspended solids.

There are some inherent limitations with the model approach presented here. For example, the model does not predict vertical structure of conservative constituents (e.g., salinity) and, therefore, does not allow analysis of stratification. Nevertheless, the model does provide a relatively simple, cost-effective approach for examining gross movement of waterborne substances in the Bay and long-term changes in Bay water quality parameters.

3. Report: Ecological Study of the Perdido Drainage System -Final Review. Florida Department of Environmental Regulation. See Taylor, John L., 1993.

This report is a scientific review of Dr. Robert J. Livingston's report, Ecological Study of the Perdido Bay Drainage System, which consists of twelve chapters and forty appendices, comprising a total of approximately 15,000 pages. The report was prepared according to a contract between the Florida Department of Environmental Regulation and Taylor Biological Company, Inc. In conducting this review, it was required that particular emphasis should be placed on whether the findings and conclusions on the impact of the Champion Pulp Mill on Elevenmile Creek and Perdido Bay are substantiated by the field and laboratory data collected during the study. The scientific review is a 40 page document.

D. U.S. Department of the Interior

1. Report: Effects of Pollution on Water Quality, Perdido River and Bay, Alabama and Florida. See U.S. Department of the Interior, 1970.

On April 7, 1969, the Southeast Region of the Federal Water Pollution Control Administration received a request for technical assistance from the Director, Technical Staff, Alabama Water Improvement Commission in evaluating water quality conditions and waste sources in Perdido Bay. An investigation of waste sources and a detailed study of the bay and its major tributaries were conducted during the period of September 9-17, 1969. This report presents an evaluation of the data collected during this study.

The inadequately treated waste effluent from the St. Regis Paper Company at Cantonment, Florida is the major cause of the low dissolved oxygen, unsightly foam, excessive sludge deposits, and increased lignin in Perdido Bay and River, as well as degraded water quality in Elevenmile Creek. Water quality problems in the mouth of Bayou Marcus are caused by the collective discharges to the bayou from six small treatment facilities, the most significant of which are the Mayfair, Montclair, and Avondale plants.

To abate the existing pollution in Perdido River and Perdido Bay, the following water quality management and waste abatement program is recommended as a minimum:

1) An overall removal efficiency of 90% for carbonaceous waste material from the St. Regis Paper Company. The St. Regis waste effluent, as measured below the present riffle terraces, not exceed 8,880 pounds per day of five-day BOD, and 2,610 pounds per day of total organic carbon. All settleable solids be removed.

2) The St. Regis Paper Company remove the foam causing constituents from its effluent.

3) The St. Regis Paper Company reduce the color of its waste discharge to levels not greater than background measured at the U.S. 90 bridge on the Styx and Perdido Rivers.

4) St. Regis Paper Company in cooperation with the Florida Department of Air and Water Pollution Control make a feasibility study of construction of an essentially closed system involving recirculation, treatment and reuse of its process water. This report shall be submitted to the Conferees by January 1, 1971.

5) The six sewage treatment plants on Bayou Marcus be consolidated into a central facility with removal efficiencies of 90% for carbonaceous material.

6) All waste abatement facilities be in operation by January 1, 1973.

E. U.S. Environmental Protection Agency

1. Report: Report on Elevenmile Creek, The Receiving Stream for Champion International Corporation. See EPA, 1988.

Simulations using a calibrated and verified mathematical water quality model of Elevenmile Creek reveal problems with seasonally depressed dissolved oxygen levels below the 5 mg/L water quality criteria. The DO depression occurs as a result of the combined carbonaceous and nitrogenous oxygen demand associated with Champion's discharge. Little improvement can be expected in removing any additional carbon from their discharge with the existing wastewater treatment system. The treatment system operates near maximum removal efficiency for a secondary biological treatment facility. However, much could be gained if Champion could control the ammonia nitrogen in their discharge. Benefits to the Creek would induce increased oxygen levels and the reduction or elimination of potential toxicity associated with the un-ionized ammonia. Even with the added benefits associated with additional ammonia removal, the Creek could not meet the assigned dissolved oxygen standard.

1) Champion achieved better than 95% removal of BOD_5 and TSS based on self-monitoring data from January 1987 to December 1988; a near maximum efficiency for a secondary biological waste treatment facility.

2) During that same period Champion's discharge exceeded the maximum allowable un-ionized ammonia criteria (0.02 mg/L) 87% of the time based on daily self-monitoring data. Un-ionized ammonia in excess of the maximum criteria has been shown to be toxic to fresh water and marine animals.

3) Bioassay studies of Champion's discharge conducted during April 1987 and September 1987 revealed no acute toxic response but did show a chronic response in reproduction of the test organism (daphnid).

4) A calibrated and verified water quality model predicts an allocation for Champion that may not be achievable with their existing secondary biological waste treatment facility.

5) The free flowing portion of Elevenmile Creek assimilates at best 30% of the ultimate CBOD discharged from Champion. The remaining 70% of the oxygen demand is exerted in the embayed portion of Elevenmile Creek, Perdido Bay, and the Gulf of Mexico.

6) Sampling for benthic macroinvertebrates revealed a depauperate community limited in species and diversity compared to other streams in the panhandle area.

7) The oxygen demand associated with Champion's discharge depresses DO in Elevenmile Creek below the 5 mg/L water quality standard during certain seasonal periods.

8) Removal of the excess ammonia from Champion's discharge will improve DO conditions in Elevenmile Creek approximately 0.7 mg/L and will reduce the potential toxicity associated with the un-ionized ammonia fraction.

9) Champion discharged an average of 59, 57, 30, and 22 percent of the respective TOC, NH_3, total phosphorus and TSS load to Perdido Bay during the basin wide surveys while contributing only 4 percent of the freshwater flow.

The oxygen demand associated with Champion's waste discharge is in excess, at times, of Elevenmile Creek's natural assimilative capacity. The result is an instream DO of 5 mg/L is not met during low flow and high temperature conditions. Even with ammonia removal, the existing secondary treatment system may not be capable of producing effluent which would allow the creek to maintain the assigned standard. Accordingly, Champion needs to consider pursuing an alternative technology to decrease or abate their present waste load to Elevenmile Creek.

2. Report: Perdido Bay as a Long-Term Gulf Region Estuarine Ecosystem Verification Template. See Flemer, 1989.

ABSTRACT

Functional integration of monitoring and research is described for Perdido Bay, a representative northern Gulf of Mexico bayou-type estuary. The site is proposed as a long-term research study site for the U.S. Environmental Protection Agency (EPA) Environmental Research Laboratory, Gulf Breeze (ERL/GB). The research strategy is tiered. Tier 1 includes base-line monitoring in a long-term time series (e.g., monthly) for hydrographic, climatic and ecological variables (e.g., plankton, benthos, submerged aquatic vegetation and icthyofauna). Tier 2 provides for special field studies that require a sampling regime incompatible with a monthly sampling frequency (e.g., event oriented). Emphasis is placed on analysis of factors such as storms or extreme tides that control the strength of the pycnocline, hypoxic events, and larval and post-larval recruitment. Tier 3 focuses on laboratory and field experiments and field manipulations (e.g., microcosms, field transplant studies, and field cages). This tier includes ecotoxicological studies, especially those designed to test for indirect effects. Tier 4 includes conceptual, statistical, and process mathematical modeling (e.g., food web trophodynamics, energy flow, mass balance, and hydrodynamic and nutrient kinetic process models).

The proposed framework provides an opportunity for multi-disciplinary lab-to-field validation studies from suborganismic to ecosystem levels of ecological organization. Emphasis is on a basic core research program that contributes to improved cause-effect analysis and prediction of ecological effects that distinguish between anthropogenic and natural perturbations.

The framework outlines a strategy that addresses the fundamental question of how properties relate across scales which are basic to solving problems of extrapolation and determining the ecological significance of changes in particular ecosystem sub-units. A programmatic and scientific rationale defines Perdido Bay's potential as a strong candidate as a regional and national long-term estuarine ecosystem verification template to evaluate concepts and indicators of ecological stress in support of the Agency's Gulf of Mexico Program and the Office of Research and Development's Near Coastal Environmental Monitoring and Assessment Program.

Perdido Bay is large enough to be representative of northern Gulf estuaries and yet small enough to allow critical field and laboratory experimentation of unusually high transfer values. Moreover, the activities proposed will provide information about estuarine processes and structure directly applicable to management and regulatory interests.

3. Report: Evaluation of the Gulf of Mexico Sediments Inventory. See EPA, IN DRAFT(A).

The Technical Steering Committee (TSC) of the Gulf of Mexico Program charged the Toxic Substances and Pesticides subcommittee to evaluate the impact and potential impact of toxics and pesticides on nearshore areas of the Gulf of Mexico. The Subcommittee responded to the TSC's request through preparation of 3 preliminary reports to establish whether or not a problem exists. The first report was an evaluation of the Toxics Release Inventory for the Gulf of Mexico (TRIGM). This document will be the second report, and it will evaluate the Sediment Quality Inventory for the Gulf of Mexico (SQIGM). A third report is forthcoming. It will integrate the findings of the first two reports and characterize the sources and sites of contamination in Gulf of Mexico estuaries.

The Gulf of Mexico Sediment Inventory (GMSI) consists of sediment quality monitoring data collected by Federal, State, and private agencies, from 1980 through 1992. Data types for the inventory include: sediment chemistry, physical data, sediment toxicity tests, and tissue residue.

4. Report: Gulf of Mexico Toxic Substances and Pesticides Characterization Report. See EPA, IN DRAFT(B).

The Technical Steering Committee (TSC) of the Gulf of Mexico Program identified toxic substances and pesticides as potentially harmful pollutants to the Gulf of Mexico and directed the Subcommittee on Toxic Substances and Pesticides to evaluate the impact of these chemicals on near-shore areas of the Gulf.

The Subcommittee responded to the TSC's request through preparation of a preliminary report to establish whether or not a problem exists by producing a Toxic Releases Inventory for the Gulf of Mexico (TRIGM).

In addition, potential impacts from sediment contamination will be examined through the production of a Sediment Quality Inventory for the Gulf of Mexico (SQIGM) containing sediment chemical information from Gulf estuaries including Perdido Bay.

The purpose of the Gulf of Mexico Toxic Substances and Pesticides Characterization Report is to summarize the results of the TRIGM and SQIGM and present the results in a generalized form for use by environmental managers and other interested parties.

5. Report: Report on the XRF/CS^3 [X-ray Fluorescence/ Continuous Seafloor Sediment Sampler] Tests [in Perdido Bay]. See EPA, 1990.

Over the past several years, the Environmental Protection Agency (EPA), Region IV, and the Center for Applied Isotope Studies (CAIS) have monitored several ocean dredged material disposal sites (ODMDS) throughout the southeastern coastline of the United States. The procedure used in this program, the **continuous sediment sampling system** (CS^3), developed by CAIS, involved a rapid collection, non-destructive method for assessing and mapping the sediment quality according to the elemental content of the survey area.

A growing concern exists for the need to rapidly map and monitor the contaminants found in our nation's estuarine environment. Pollutants introduced into the marine environment eventually settle and become part of the sediments found on the bottom of the rivers and bays. For this reason, the EPA, Region IV, and CAIS entered into a cooperative agreement.

A new state-of-the-art **x-ray fluorescence** (XRF) analysis was needed to increase the sensitivity and accuracy of the results of the sediment samples retrieved during the survey. Operating procedures needed to be developed to adapt the XRF to the type of sediment samples produced by the sample processor used on board the survey vessel during the survey. With the new XRF, a better understanding of the river and bay sediments could be achieved by increasing the range and sensitivity of elements detected and accuracy of the maps generated for the surveyed area.

Perdido Bay was known to have high concentrations of unconsolidated sediments as well as deposits of sand. This location appeared to be a good transitional test area between the ocean sites and fresh water rivers. By analyzing the samples from Perdido Bay, a data bank of sample analyses can be stored for future comparison and use in the ocean mapping software.

The analyses from sediment samples were evaluated by the same software used in the ocean mapping program. The maps show the elemental distribution of the twenty elements measured by the XRF.

From the tests performed at Perdido Bay, Florida, a better understanding of the deployment and operation of the CS^3 for a survey in a river or bay was obtained.

6. **Survey: Perdido Bay Reconnaissance and Survey Data**, July 1986; December, 1986; April, 1987; July, 1987; October, 1987. See EPA, 1987.

An EPA data base for Perdido Bay for survey work conducted during July and December 1986; and April, July and October 1987. Information contained within the data base includes: dissolved oxygen, salinity, temperature, light transmission, water flow, sediment-metals, sediment particle size, biochemical oxygen demand, and nutrient chemicals. Stations are located primarily in the upper Bay and streams and rivers tributary to the Bay.

F. Peer-Reviewed Research Papers

1. Abnormal Expression of Secondary Sex Characters in a Population of Mosquitofish, _Gambusia affinis holbrooki_: Evidence for Environmentally-induced Masculinization By W. Mike Howell, D. Ann Black and Stephen A. Bortone. 1980.

ABSTRACT

Paper mill effluents are discharged into **Elevenmile Creek** at Cantonment, Escambia County, Florida. The total population of mosquitofish, _Gambusia affinis holbrooki_, inhabiting the stream below the effluent discharge exhibits abnormal sexuality. All females are strongly masculinized, displaying both physical secondary sex characters and reproductive behavior of males. Males exhibit precocious development of physical secondary sex characters and reproductive behavior. Elevenmile Creek above the paper-mill effluent, as well as tributaries to this creek, all contain _Gambusia_ with normal secondary sex characters. This evidence strongly suggests that some yet unidentified chemical or combination of chemicals associated with the paper-mill effluent exerts a strong androgenic effect upon this population. This constitutes the first report of possible environmentally-induced masculinization involving a total natural population of vertebrates.

2. Laboratory Induction of Intersexuality in the Mosquitofish, _Gambusia affinis_, Using Paper Mill Effluent By Dale T. Drysdale and Stephen A. Bortone. 1989.

Intersexual traits have been described in a wild population of mosquitofish in a northwest Florida (USA) stream which receives effluents from a paper/kraft mill (Howell _et al_. 1980). Adult female _Gambusia affinis_ taken as far as 15 km downstream of the discharge from the kraft mill effluent (KME) were phenotypically masculinized (arrehnoid), exhibiting a range from imperfect to well-developed examples of gonopodial anal-fins and exhibiting elements of male reproductive behavior.

To test the hypothesis that masculinization of natural _Gambusia affinis_ populations was induced by a KME-borne androgen or androgen-like substances newly hatched laboratory-reared offspring were experimentally exposed to KME-receiving streamwater.

Adult male and female G. affinis stocks were collected from streams receiving no KME in Escambia and Santa Rosa Counties in northwest Florida (USA).

Gravid females were transferred to separate 3-L glass containers, which served as breeding aquaria.

Young (1-3 day old) fish were removed and placed in aquaria containing streamwater that received KME (4-L glass containers with 3-L of aerated water collected from **Elevenmile Creek** [Escambia County, Florida, USA] at a site 3.6 km downstream from the point of KME discharge) or non-KME receiving streamwater (in similar sized aquaria as the exposure aquaria above) and daily fed identical portions of live brine shrimp (Artemia) nauplii.

Differences between KME-exposed and non-KME exposed fish with regard to their anal fin length were evident.

The present research has provided evidence that the agent responsible for the intersex condition of poeciliid fishes is an androgen, androgenic-like compound, or androgen precursor borne by the water and perhaps later modified by microbial action in the environment.

3. Effects of Kraft Mill Effluent on the Sexuality of Fishes; An Environmental Early Warning? By William P. Davis and Stephen A. Bortone. 1992.

In this report we describe arrhenoidy (i.e., masculinization) in females of the fish family Poeciliidae sampled from streams receiving kraft mill effluent (KME) and among fish experimentally exposed to microbially degraded phytosterols. The masculinization response involves development of male secondary sex morphological characters, including modification of the anal fin into a gonopodium-like structure, often concomitant with male fish behavior, including mating attempts.

Initial discovery of arrhenoid female mosquitofish, Gambusia affinis, was made during a field survey of **Elevenmile Creek** investigating the distributional boundaries of the eastern G. holbrooki and western G. affinis, mosquitofish.

Although no surveys have been reported, arrhenoid poeciliids have not been reported or recognized widely over the warmer latitudes. The unique commonality of Elevenmile Creek and Fenholloway River (Taylor County, Florida) include industrial use of virtually the entire flow (25 and 50 mgd respectively) for KME discharge. Discovery and observation of the masculinization phenomenon was facilitated by easy access to the effluent. Most pulp mills discharge to larger waterways. This practice dilutes and potentially obscures effects described herein. Larger bodies of water will potentially have different ecological circumstances influencing microbial exposures and pathways to potentially sensitive species. Such features may be crucial in the production and availability of KME androgen precursors. It is essential to illuminate these processes and increase understanding in order to evaluate and choose potential strategies for mitigation.

Masculinization, or arrhenoidy, has been reported among livebearing poeciliid fishes living in streams receiving effluent from kraft pulp mills. The principal characteristic indicating androgenic effects of the effluent is elongation of the female anal fin into a gonopodium, which serves to transfer and insert sperm from functional male poeciliid fish. Apparent duplication of the environmentally masculinized females may be accomplished in the laboratory after exposure to various steroids. Specific phytosteroids, microbially transformed, simulate the morphological and behavioral effects observed in fishes captured from kraft mill effluent. However, specific substances in effluents remain unidentified.

Masculinization of poeciliid females appears to be permanent, the degree of response graded to concentration and/or duration and, therefore, may affect a number of life history elements that influence longevity and fitness. Exposure during early stages of the life history appears to produce the most severe responses, potentially including hermaphroditism.

The apparent graded masculinization response to presence or concentration of the androgenic factor presents a potential assessment technique to monitor effectiveness of stream water quality and treatment processes.

4. Sedimentary and Geochemical Systems in Transitional Marine Sediments in the Northeastern Gulf of Mexico By Wayne C. Isphording, John A. Stringfellow and George C. Flowers. 1985.

ABSTRACT

The coastal zone of the northeastern Gulf of Mexico is marked by a series of bays and estuaries that serve as the principal depositional basins for rivers draining an area of greater than 160,000 km. These rivers annually contribute a sediment load to the basins in excess of 12 million tons. Because each river drains a watershed of different lithologic character and each river is further characterized by a different flow regime and hydraulic properties, the sediments deposited in the marginal basins have their own uniqueness.

Extensive municipal and industrial "dumping" of effluent over the years has also acted to imprint geochemical differences on each of the depositional basins. Depending upon the degree of industrialization within the watershed, the bays and estuaries may be described as ranging from "heavily impacted" (Mobile Bay), "moderately impacted" (Apalachicola Bay, Mississippi Sound) or "slightly impacted" (Pensacola Bay). A strong correlation was observed between the degree of heavy metal contamination and the textural and organic content of the sediments. Analyses further indicated that most metals were partitioned in the bottom sediments in forms that would permit their subsequent release back into the water column or would allow transference of the metal to fauna by ingestion.

G. Consulting Firm Reports

1. Report: Ecological Study of the Perdido Bay Drainage System - "The Livingston Study." See Livingston, 1992

This report was finalized in July 1992. It was developed as an interdisciplinary project in order to answer complex and specific questions concerning the impact of Champion International Corporation's Pensacola Mill on Elevenmile Creek and the Perdido Bay system. An ecosystem approach was used because the mill's impact could not be evaluated without first determining the effects of natural (background) conditions and of additional human activities in the Perdido system. The study provides a review of field work and analyses performed over a four-year period.

It is comprised of twelve chapters and forty appendices totalling 15,000 pages.

Chapter 1 is entitled Summary of Results. In that chapter the results of the study are provided in the context of answers to eight important questions that involve background environmental conditions of the Perdido drainage system and the potential impact of the Pensacola mill on Elevenmile Creek and Perdido Bay.

The report includes a wealth of data, observations and conclusions beyond the scope of any brief annotation. However, the following are the observations presented at the conclusion of Chapter 1 and that seem most important for a summary statement about the report:

Question 8. If the Pensacola mill is having an adverse effect on the Perdido system, what forms of mitigation can be developed to restore the habitat quality and aquatic productivity? Can the data be used to manage the system?

Mill effects on Elevenmile Creek are relatively straightforward. Increased organic compounds (hypoxia, altered food webs), high free ammonia (toxicity), increased specific conductance (osmotic imbalance), high color and turbidity (altered light characteristics), release of toxic agents (EOCl); [extractable organically-bound chlorine], and increased nutrient loading (potential bay hypereutrophication) have been addressed in the scientific assessment of the Perdido system. Hypoxia in Elevenmile Creek is exacerbated by the release of organic compounds and present a problem in various parts of the creek periodically. The high levels of free ammonia in the upper creek, along with high specific conductance, contribute to the loss of sensitive species in these areas. Color levels have been reduced substantially by the Pensacola mill, and water color does not present a problem at the current levels. Relatively low concentrations of EOCl have been noted in organisms along Elevenmile Creek, and, although there is no evidence of physiological stress, these concentrations do represent a form of toxic agent that is currently present in the creek and associated areas of the upper bay. The increased nutrient loading, aside from potential effects on dissolved oxygen, do not present a significant threat to the creek. The management of these factors would include reduction of the various components to levels compatible with the assimilative capacity of Elevenmile Creek.

The impacts of the mill on Perdido Bay include increased nutrients and organic matter in the immediate receiving area of the bay. There are low-level concentrations of EOCl compounds found in the sediments and organisms in the immediate receiving portions of the bay off Elevenmile Creek. These concentrations have been associated with mill discharges. Although there is no indication of a toxic effect from such compounds, EOCl concentrations do represent the presence of toxic substances in the receiving estuary. These substances have also been found in other areas of the bay, and the exact source(s) of such substances has (have) not been determined. There is no evidence of metal contamination in Perdido Bay that can be associated with the Pensacola mill. From the descriptive and experimental data, there is considerable evidence that the current light transmission characteristics of Perdido Bay are not being affected adversely by mill discharges, and that the submerged aquatic vegetation in the bay is not being adversely affected by water from Elevenmile Creek.

The increased levels of nutrients and organic matter in the immediate receiving area of the bay off Elevenmile Creek is somewhat problematical in terms of a management perspective. The releases of nutrients from the creek are associated with increased primary and secondary production in the immediate receiving areas of the bay. The dominant populations that appear to be associated with these discharges include commercially valuable species such as blue crabs, penaeid shrimp, and certain finfish. The shallow portions of the upper bay are actually quite productive, based on comparisons with other estuarine systems that are considered to be relatively free of human impact (including pulp mills). Phosphorus loading to the bay should be evaluated along with a more in-depth analysis of the nutrient and organic loading to the Perdido River system. The ammonia levels at depth in Perdido Bay are higher than those in other estuarine systems in the northern Gulf; however, the free ammonia levels do not exceed the criteria established by the U.S. Environmental Protection Agency with regard to acute and chronic toxicity. There is no evidence of a toxic effect on organisms in the upper portions of the bay that receive direct runoff from Elevenmile Creek. The nutrient and organic carbon issue in Perdido Bay thus should be resolved on the basis of the impact of these discharges on the over-riding environmental feature of Perdido Bay: the hypoxic conditions beneath the halocline in deeper portions of this estuary. There is evidence that hypoxia is associated with reductions of useful productivity in major portions of the Perdido Bay system. Hypoxia is thus the primary management issue of Perdido Bay.

The evidence from the descriptive chemical data, the experimental (isotope studies, and the various modeling efforts indicates that the Pensacola mill is responsible for only a small proportion of the dissolved oxygen loss at depth in Perdido Bay. The major effects on bay dissolved oxygen are controlled by other factors such as salinity stratification (dredging in the lower bay) and nutrient/organic loading from as yet undetermined sources in the lower bay area. The current evidence points to at least seasonal input of these substances by municipal runoff and discharges in the lower bay. The contribution of nutrients and organic matter to the problems of hypoxia in Perdido Bay has significant management implications, not only for the Perdido Bay system, but for most of the barrier island estuaries that are currently undergoing extensive municipal development and are receiving wastes from largely unregulated agricultural activities. Ongoing dredging activities in the lower portions of such estuaries are common throughout the Gulf, and massive dredging activities continue despite mounting evidence that such activities can cause significant alterations in the salinity regimes of the associated estuaries.

A major finding of the Perdido Study is that, when compared to the upland drainages, the lower bay portions of barrier estuarine systems are as important to the wellbeing and useful productivity of the associated estuary as upland drainages both in terms of salinity control and the impact of various nutrients and organic pollutants. Nutrients, organic carbon, and toxic substances placed in waters at lower end of barrier estuaries can move in a landward direction from areas that have been traditionally subject to virtually unlimited physical alteration and municipal development. Marinas, stormwater runoff from roads and housing developments, septic tank wastes, and discharges from a variety of sewage treatment facilities from seemingly offshore sources are thus part of the problem of an inshore system such as Perdido Bay. An effective management program of the Perdido system will thus require attention of all of the contributing factors which includes not only the Pensacola mill but also the various activities associated with municipal and agricultural development.

Management of Perdido Bay will thus have to include determination and control of various sources of nutrients and organic carbon which include the Perdido River and its tributaries and municipal and agricultural sources in the entire Perdido Bay drainage area. This management should also address the impacts of physical alterations of the lower-bay if the problem of hypoxia in Perdido Bay is to be addressed in a satisfactory manner. Based on these findings, it is appropriate that a research effort be conducted on a comparable scale as the present study to determine the sources and effects of nutrients, organic matter, light-altering substances, and toxic agents in lower Perdido Bay, and to evaluate the effects of dredging on the Perdido system.

2. Report: Synoptic Analysis of Water and Sediment Quality in the Perdido Drainage System. See Isphording and Livingston, 1988.

Perdido Bay is a shallow estuarine system that is physically forced by freshwater runoff and other climatological events. Rapid changes in hydrology and water quality were noted as functions of wind events, salinity stratification, and temperature conditions. Hypoxic conditions at depth appeared to be associated with such variables, although causative factors were not determined. Low bottom dissolved oxygen appeared to be related to high water temperature and high salinity stratification. The Perdido River is a dominant source of sediments to the bay. Over the period 1982 to 1988, there were some changes in the bay sediments. The upper bay shifted from a mostly sandy substrate to a sand/silt/clay mixture. There was a bay-wide shift to coarser sediments that could be related to development activities and storm water runoff in the Perdido basin. The concentrations of carbonate carbon and organic carbon in Perdido Bay sediments were comparable to those in other estuaries in the NE Gulf of Mexico. Organic carbon values were lowest in the shallower portions of the bay. No anomalies were noted in the sediment pH and Eh (redox) values of Perdido Bay relative to other Gulf systems. Somewhat higher illite (clay mineralogy) concentrations were noted in the upper bay and were ascribed to river influences. Metal concentrations (Cd, Co, Cu, Cr, Ba, Zn, Fe, Va., Al) in Perdido Bay sediments were comparable to those in other bay systems in the NE Gulf and only iron could be detected in water samples. Ion site partitioning in pore water indicated that the greater portion of most of the metals tested (with the exception of chromium and vanadium) in the sediments of Perdido Bay are available to the biota. Based on the evaluation of bottom sediment textures, mineralogy, inorganic water chemistry, and the site partitioning behavior, there is no evidence that the

Pensacola paper mill has had an adverse effect on Perdido Bay sediments. Relatively low organic carbon and high percentages of coarser-grained sediments indicate only limited sites for the accumulation and attachment of contaminants that enter the bay. The relationship of the sediments to the hypoxic conditions noted at depth remains undetermined.

H. Industry Reports

1. Data: Water Quality, Sediment and Tissue Data. See Champion International Corporation, 1993.

The Champion International Corporation has on file various unpublished records from 1984 through 1993 related to the Cantonment Mill, Elevenmile Creek, and Perdido Bay involving water, sediment and biotic tissue data. Although the data are corporate records, Champion has made much of the data available for public review.

2. Report: Dioxin Monitoring Program - Florida Pulp and Paper Association. (Specific Mill Field Study Design: Champion International Corporation - Cantonment, Florida.) See ENSR, 1989.

The report, produced in 1989, describes the Florida Pulp and Paper Association's design for a dioxin monitoring program for six paper mills in Florida. It includes a specific mill field study design for the Champion International Corporation's Cantonment Mill. The program includes descriptions of sampling methodologies, standard operating procedures and analytical procedures for effluent, sediment, fish and molluscs. Although some sampling has been completed by the Cantonment Mill, the FPPA Dioxin Monitoring Program has not yet been fully implemented. The Program was submitted to EPA May 19, 1989.

3. Report: Summary Report of Fish Sampling in Elevenmile Creek for Analyses of 2,3,7,8-TCDD and 2,3,7,8-TCDF. See ENSR, 1991.

Champion International Corporation requested that ENSR Consulting and Engineering obtain fish samples from Elevenmile Creek, Escambia County, Florida, and analyze them for the presence of dioxin in fish tissues. Elevenmile Creek is the receiving water for wastewater discharges from Champion's Pensacola Mill located in Cantonment, Florida.

The analytical measurement methods used in the study involved the most sensitive methods available. High-resolution gas chromatography and high-resolution mass spectrometry were used in place of the traditional quadrapole mass spectrometry. This high-resolution analysis is capable of detecting parts per quadrillion (ppq) of dioxin in water and parts per trillion (ppt) in fish tissues. Analytical sensitivity was important because it was anticipated that the Champion pulp mill was contributing only low levels of dioxin, if any, to the environment.

The dioxin materials to be analyzed were 2,3,7,8-tetrachlorodibenzo-para-dioxin (2,3,7,8-TCDD) and 2,3,7,8-tetrachlorodibenzo-para-furan (2,3,7,8-TCDF). The 2,3,7,8 isomers are thought to be the most toxic of the various dioxin isomers (TCDF is less toxic than TCDD) and are the isomers of concern to U.S. Environmental Protection Agency (USEPA) Region IV.

Analytical results indicated that fish tissue from Elevenmile Creek composite samples had concentrations of 2,3,7,8-TCDD and 2,3,7,8-TCDF below the detection limit of 1.0 ppt.

II. Overview of Sampling Stations

Water quality and sediment sampling stations have been established by several agencies, institutions, consulting firms and corporations throughout Perdido Bay, Perdido River (and its tributaries) and the other major sources of water flowing into the Bay. The primary sampling areas and stations within the Bay are shown in Figures 2 through 7. The station numbers in the figures are the identification numbers assigned by investigators during each study. The major investigations have been conducted by the U.S. Environmental Protection Agency (EPA=O); the Florida Department of Environmental Regulation (FDER= □); the U.S. Fish & Wildlife Service (USFWS= *) and Tierra Consulting (TC= △). Examination of the figures reveals that a significant amount of survey and evaluation within Perdido Bay has taken place.

For this report, a sampling "station" was defined as a specific location for which latitude and longitude information and sediment/chemical data existed. Chemical analyses for 32 metals have been run at numerous stations within the Bay (Table 5). There has been only limited analysis for some metals. For instance, only four sediment samples were analyzed for tin. But, for most metals numerous sediment samples were analyzed. For example, 97 samples were analyzed for cadmium, 318 for chromium, 108 for mercury, 81 for silver, 257 for lead and 318 for zinc. A great number of the samples (210 of the stations for 16 metals) were run during the cooperative tests (EPA and University of Georgia) using the XRF/CS^3 "sled" (EPA 1990).

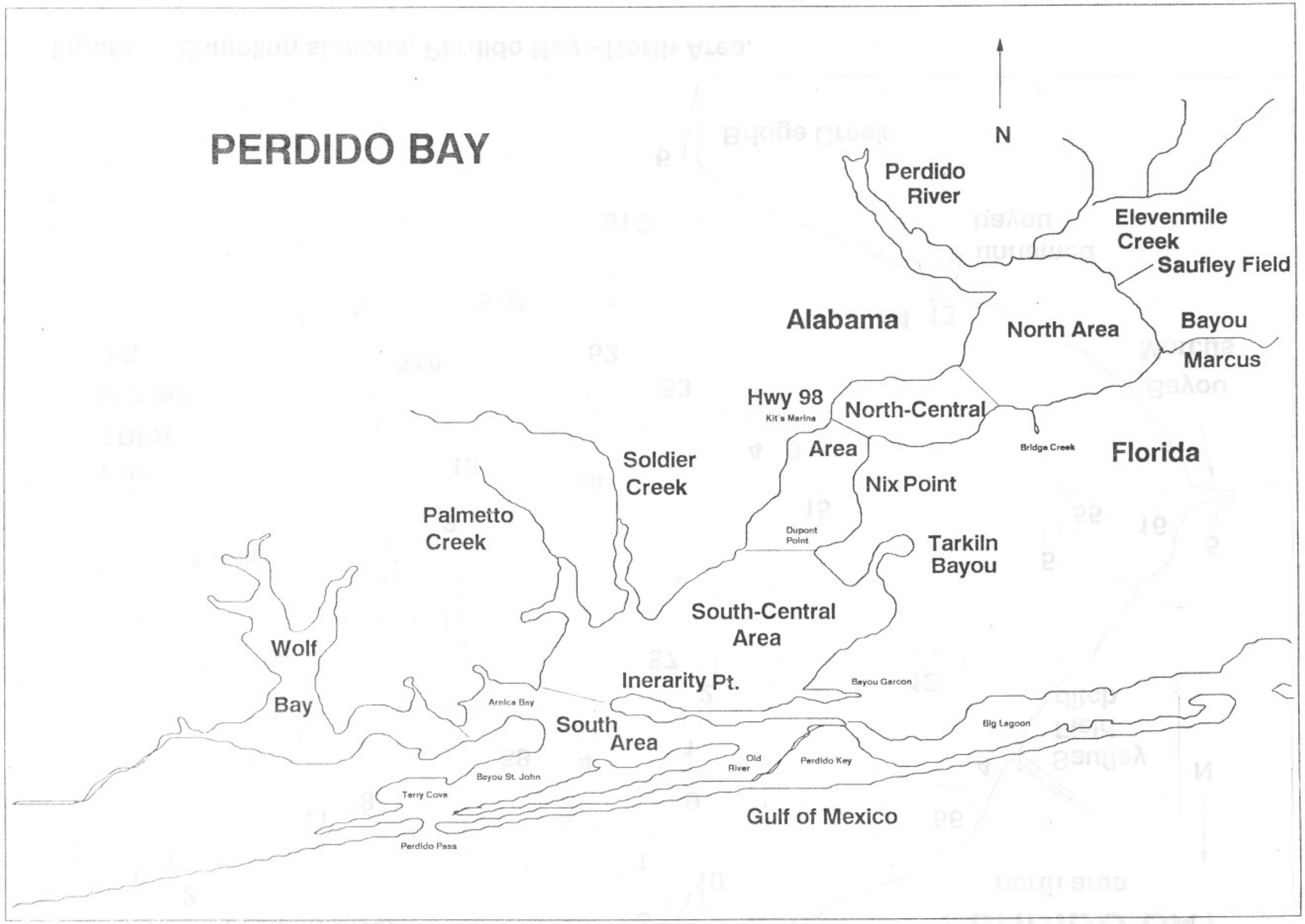

Figure 2. Perdido Bay sampling areas.

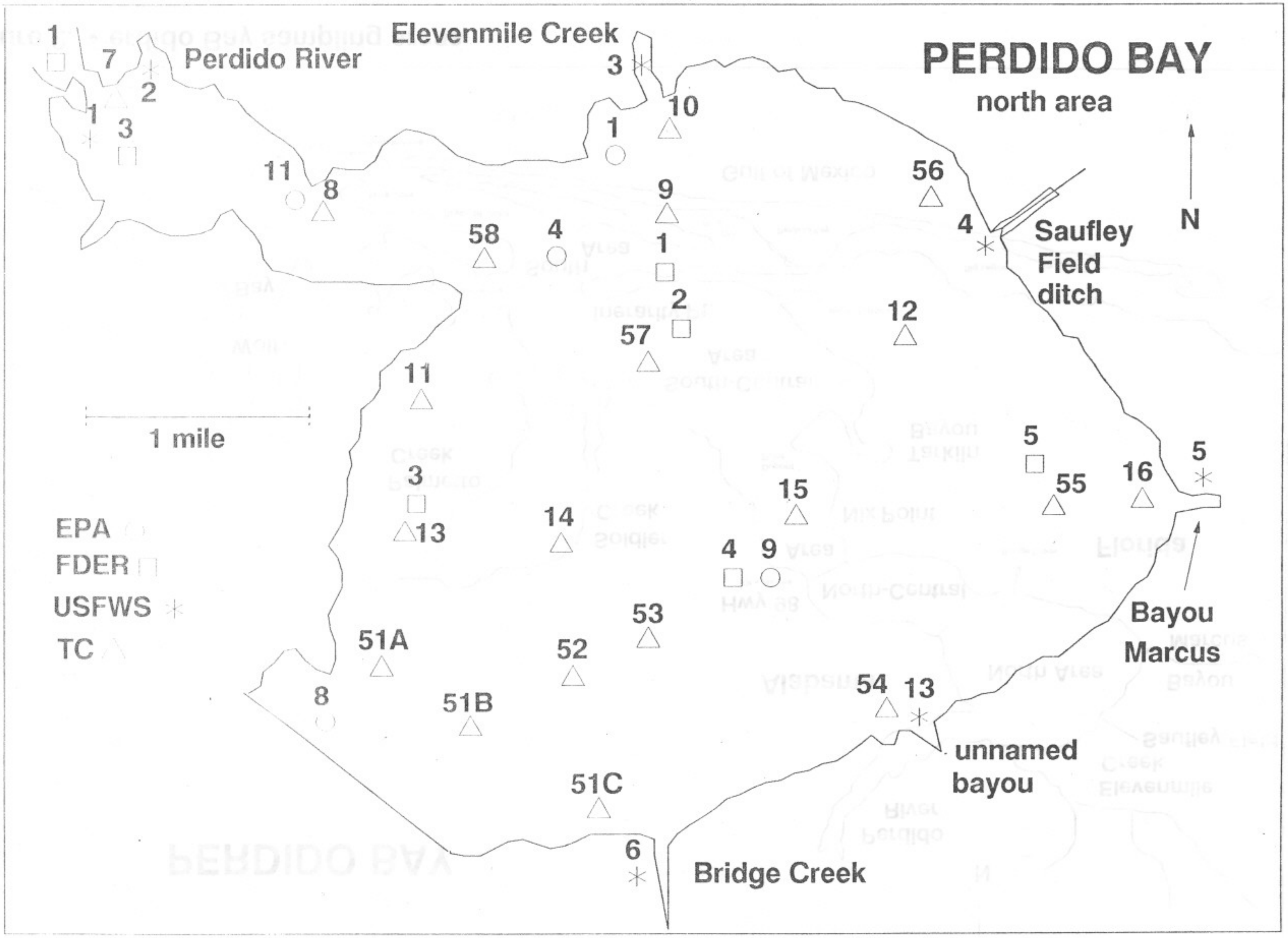

Figure 3. Sampling stations, Perdido Bay - North Area.

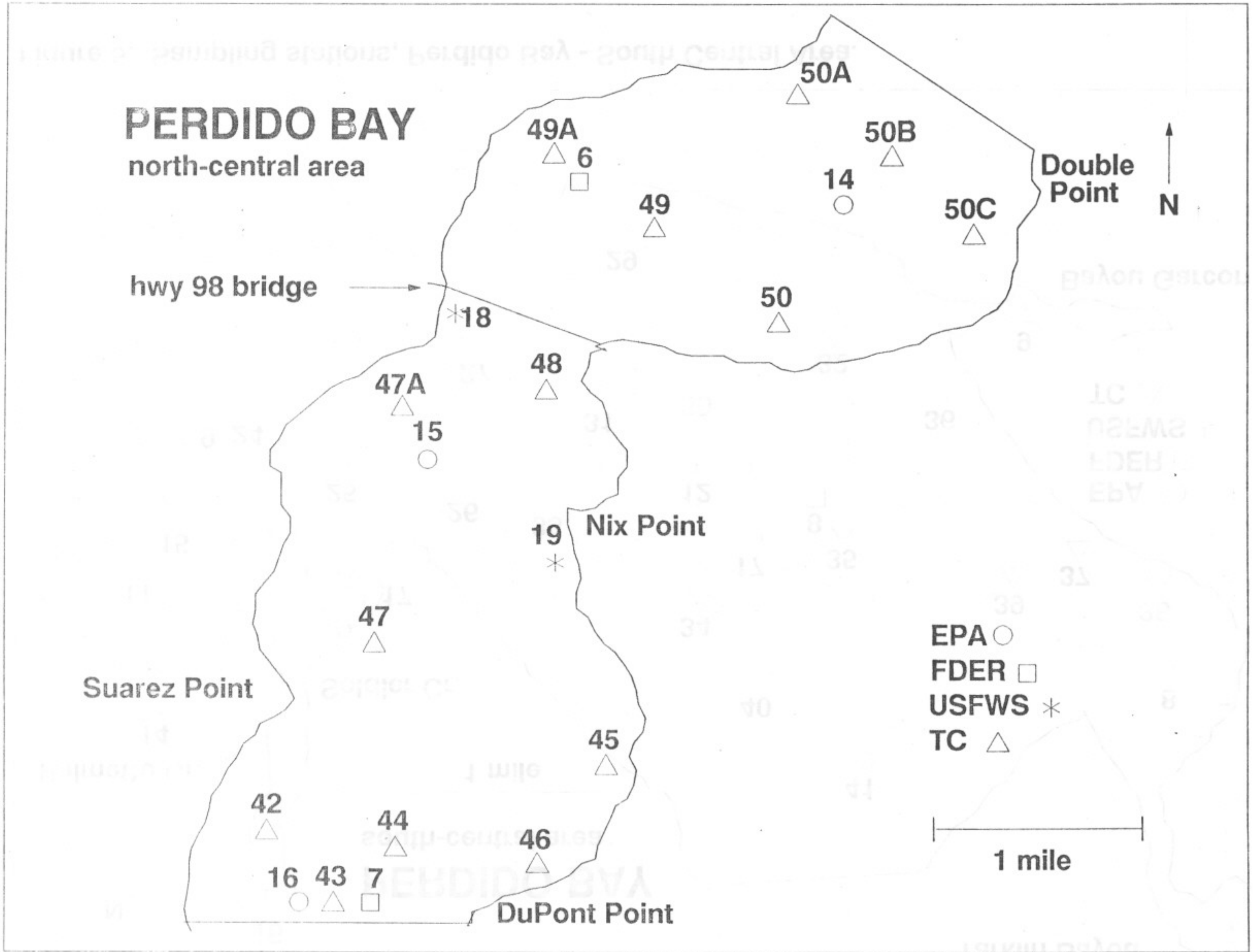

Figure 4. Sampling stations, Perdido Bay - North Central Area.

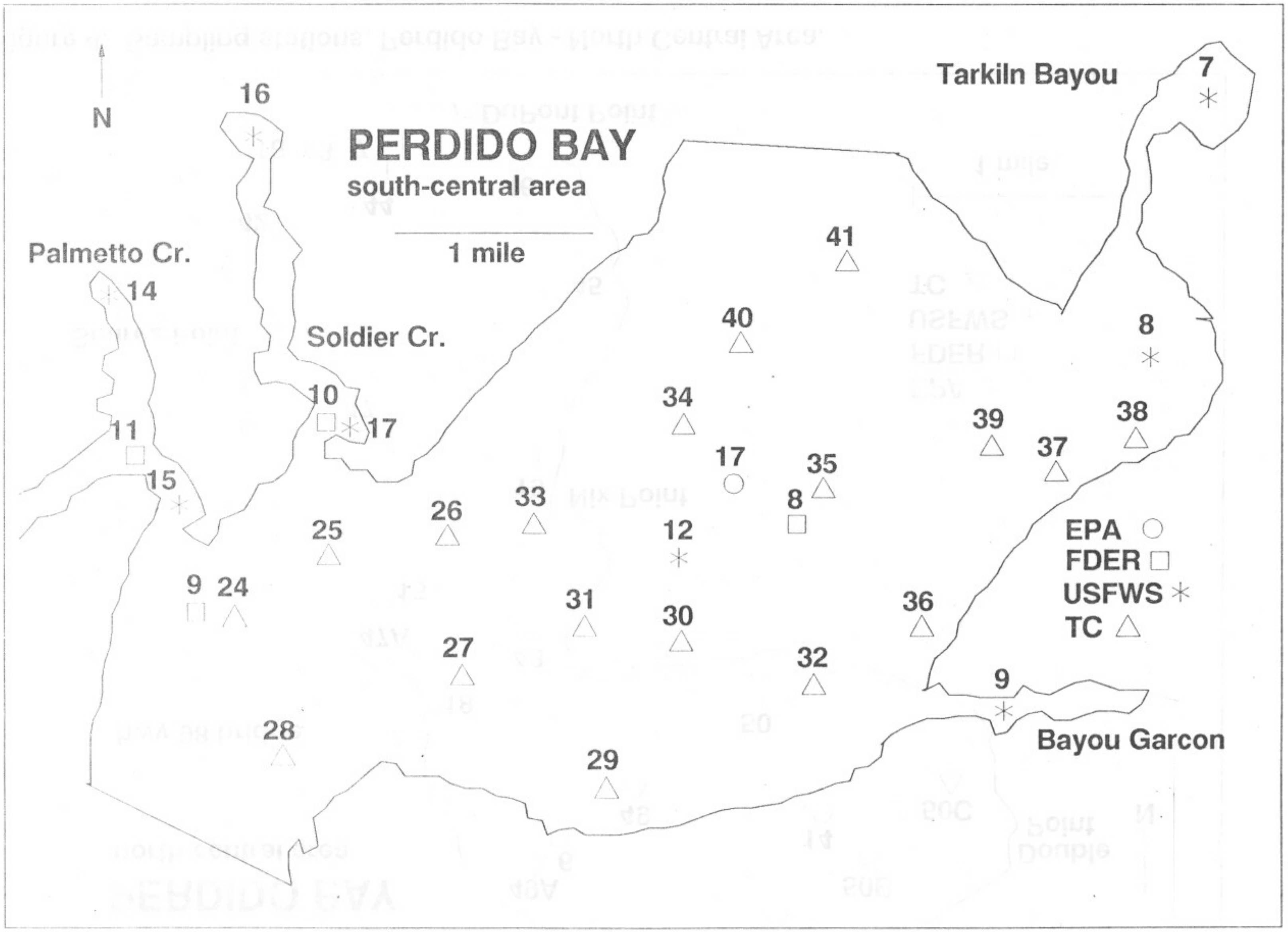

Figure 5. Sampling stations, Perdido Bay - South Central Area.

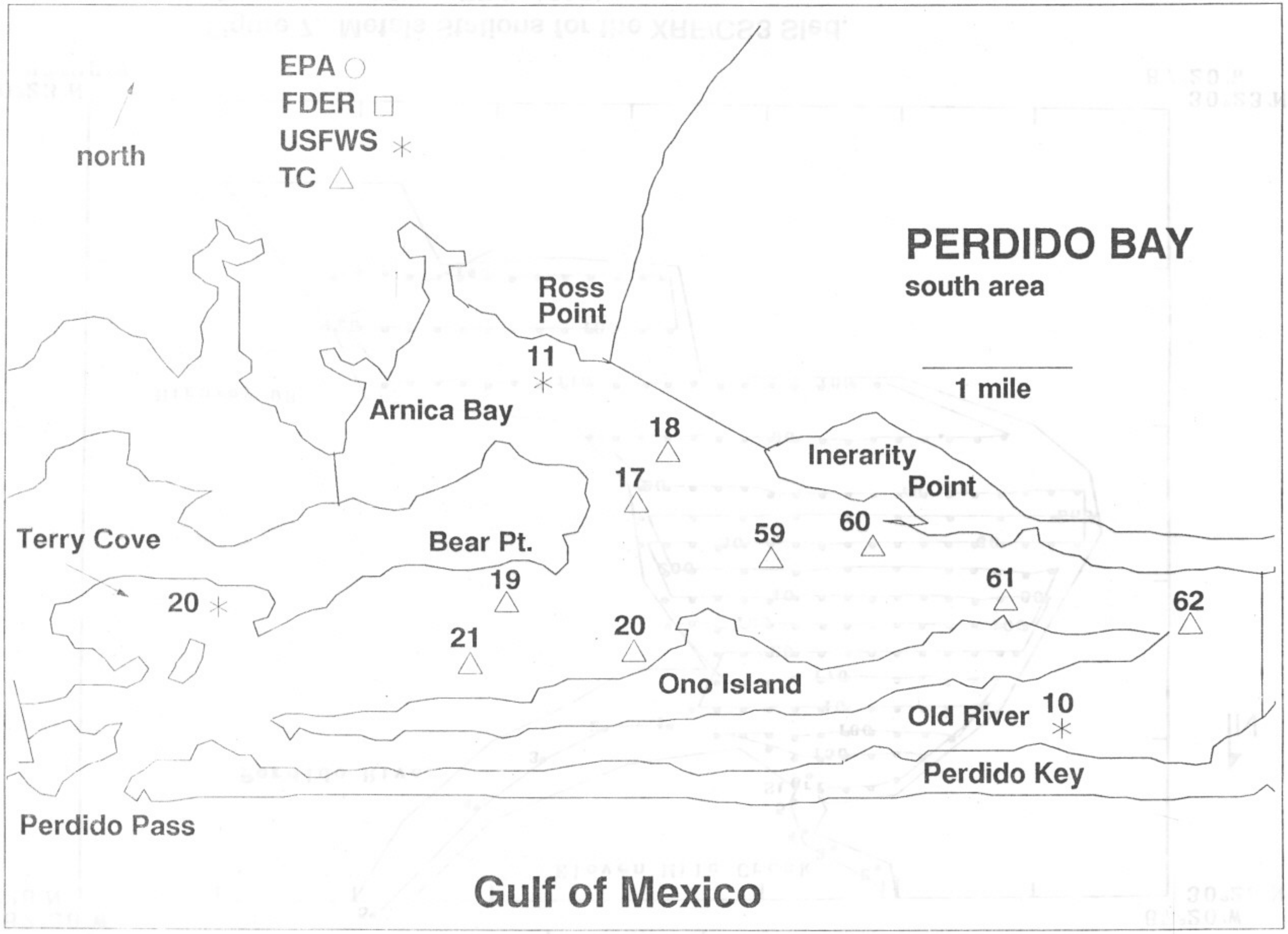

Figure 6. Sampling stations, Perdido Bay - South Area.

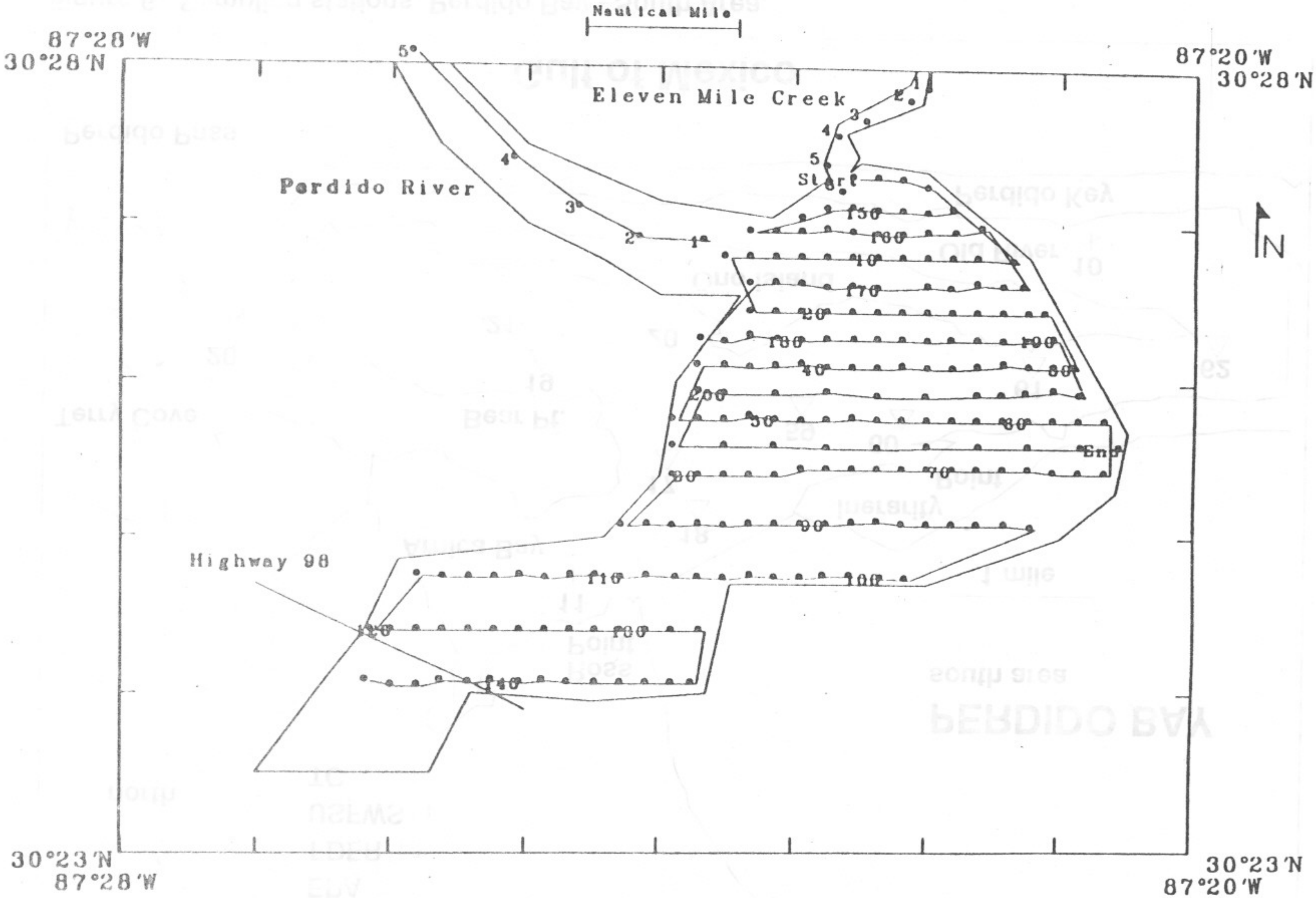

Figure 7. Metals Stations for the XRF/CS3 Sled.
(Reproduced from EPA, 1990)

Table 5. Chemical Contaminant SEDIMENT-METALS Data Base for Perdido Bay. Figures reflect the number of sediment stations per data type.

Data Type	USEPA*	USFWS	FDEP**	TIERRA	TOTAL
Grain Size	13	24	0	61	98
% TOC	13	24	17	61	115
Partitioning	0	0	0	4	4
Al/metal test	0	24	12	0	36
Aluminum	221	24	12	61	318
Arsenic	0	24	12	0	36
Barium	221	24	0	61	85
Beryllium	0	24	0	0	24
Boron	0	24	0	0	24
Cadmium	0	24	12	61	97
Calcium	221	0	0	0	221
Chromium	221	24	12	61	318
Copper	221	24	12	61	318
Cobalt	210	0	0	61	271
Iron	221	24	0	61	306
Lead	221	24	12	0	257
Magnesium	221	24	0	0	245
Manganese	221	24	0	0	245
Mercury	11	24	12	61	108
Molybdenium	0	24	0	0	24
Nickel	221	24	12	0	257
Potassium	210	0	0	0	210
Rubidium	210	0	0	0	210
Selenium	0	24	0	0	24
Silicon	210	0	0	0	210
Silver	0	20	0	61	81
Sodium	11	0	0	0	11
Strontium	221	24	0	0	245
Sulfer	210	0	0	0	210
Thalium	1	20	0	0	21
Tin	0	4	0	0	4
Titanium	221	0	0	61	282
Vanadium	221	24	0	61	306
Yttrium	11	0	0	0	11
Zinc	221	24	12	61	318
Zirconium	210	0	0	0	210

* Includes data from the XRF/CS3 sled tests.
** Includes data from the ADEM/FDER Perdido Bay Interstate Report.

Table 6 summarizes the sediment station/chemical analyses information for organic compounds. Examination of the table reveals that little organic analyses work has been performed. Most of the analytical work (involving 33 sediment samples) has been directed toward the chlorinated pesticides, polychlorinated biphenyls (PCBs) and the polynuclear aromatic hydrocarbons (PAHs). No analytical data were found for the newer pesticides (organophosphate and carbamate compounds) and little data exists about the distribution of dioxin compounds. Few water quality data exist for chemical contaminants in the open waters of the Perdido Bay ecosystem. The vast majority of water samples were analyzed for nutrient compounds rather than toxic chemicals (Schropp et al. 1991). However, there are effluent data for the major NPDES point sources; and water quality data exist for some superfund hazardous waste sites. Very few contaminants were detected in the Service's water samples from open water areas (see Part 5 of this report). This is not particularly surprising because most of the compounds are hydrophobic and readily adhere to particulates. They quickly become associated with the sediments where they can enter the biotic food chain via bacteria, various marine worms and other macrobenthic invertebrates. Vertebrate animals such as fish and birds feed upon these invertebrates and thereby accumulate chemicals.

Table 6. Chemical Contaminant SEDIMENT-ORGANICS Data Base - Perdido Bay. Figures reflect the number of sediment stations per data type.					
Data Type	USEPA	USFWS	FDER*	CIC**	TOTAL
Grain Size	4	21	9	3	37
% TOC	3	21	9	3	36
Extractable Organics	3	0	9	0	12
Chlorinated Pesticides	3	21	9	0	33
Purgeable Organics	3	0	9	0	12
Organophosphate Pesticides	0	0	0	0	0
Carbamate Pesticides	0	0	0	0	0
Other Pesticides	0	0	0	0	0
Polychlorinated Biphenyls (PCBs)	3	21	9	0	33
Aliphatic Hydrocarbons	0	0	9	0	9
Polynuclear Aromatic Hydrocarbons (PAHs)	3	21	9	0	33
Dioxin Compounds	0	5	0	3	8

* Includes data from the ADEM/FDER Perdido Bay Interstate Report.
** Champion International Corporation

PART FIVE - FISH AND WILDLIFE SERVICE ENVIRONMENTAL CONTAMINANTS EVALUATION

TRUST RESOURCES

The goal of the Service's Environmental Contaminants Program is to assure the welfare of trust resources and the habitats these resources use. Service trust resources include Federally-listed endangered and threatened species, migratory birds, some marine mammals, and anadromous fishes; i.e., those fish species living in marine waters and moving regularly to freshwater areas to spawn, rest and feed. Service-owned lands, such as National Wildlife Refuges, are also trust resources.

The Perdido Bay ecosystem (drainage basin) provides habitat for many trust resource species. A wide variety of migratory bird life inhabits the ecosystem. Endangered species such as the bald eagle, sea turtles, eastern indigo snake and the threatened anadromous Gulf sturgeon are known to use the area. Reynolds (1993) reported possible Gulf sturgeon sightings in Perdido River and Perdido Bay. Other anadromous fishes such as striped bass and Alabama shad also occur in the ecosystem. The Perdido Bay drainage basin provides valuable habitat and food species upon which our trust resources depend.

PROGRAM DESIGN

The objective of the Service's environmental contaminants field work in Perdido Bay was to supplement the existing body of contaminant information and assist in addressing several management concerns. An estuary is a complex ecosystem that requires an extensive amount of technical information for proper management. After a review of the existing information and a survey of the types of related studies that were currently underway, five basic activities were selected, as tools, to obtain further needed information. These activities were: 1) a survey of sediments at sites not previously evaluated, 2) an assessment of fish health through gross fish examinations, supplemented with histological examination of a subsample, 3) laboratory analyses of fish tissues for chemical residues, 4) a 10-day toxicity test of sediments and water from several sites in the ecosystem, and 5) a special sediment and fish dioxin evaluation, limited to the environment of Elevenmile Creek. What follows are the results of these five activities.

WATER QUALITY DATA

A limited number of water quality analyses were run during the Service's work in Perdido Bay. These analyses were done in association with the ten-day toxicity test described in a section below. Water used as test medium for that test was collected from four locations. Analyses of filtered "F" [0.45 μm membrane] and unfiltered "UF" water samples were done on 24-hour composite samples. The samples were collected from Elevenmile Creek immediately below Champion International's treatment facility and from the Perdido River at U.S. Highway 90. Chemical analyses were also run on grab samples from lower-Perdido Bay (Station PR-12) and middle-Perdido Bay (Station PR-19), (see Table 8).

Both filtered and unfiltered samples were analyzed to determine the quantities of chemicals dissolved in water (filtered samples), and the total quantity of chemicals either suspended or dissolved in the water column (unfiltered). Chemicals often become bound up with particulate organic matter, clay or silt, that is suspended in the water column. In addition, some essential elements, such as zinc and copper, occur in concentrated amounts in phytoplankton (drifting one-celled plants) also suspended in the water column. Filtered water samples better reflect the amount of a contaminant actually dissolved in the water, because the filtering process removes suspended particulate matter and plant life. Some chemicals are rapidly taken up by animals, across gill tissue or skin, when the chemicals are in a dissolved state.

Samples were placed in pre-cleaned glass containers. Metal samples were acidified to minimize precipitation and absorption on container walls, and all samples were refrigerated prior to shipment at 4° centigrade. Samples were sent to USFWS contract laboratories within 8 hours of collection.

I. Metal Analyses

Table 7 contains metals data obtained during the 1989 toxicity tests (See also Appendix 1). Some observations can be made related to those data. In a few instances, values for filtered samples exceed those for unfiltered samples. This may indicate true differences between the aliquots of water that were analyzed or may be cases of inadvertent contamination during handling of the samples in the field or laboratory. Such results must be viewed with reservation. The following discussion of each metal is preceded by the Florida and EPA water quality criteria for that metal, when such criteria are available (Florida, 1993; EPA, 1992b). The EPA criteria are for both freshwater (FW) and saltwater (SW) aquatic life. Two numerical values are established: 1) the "criterion for a continuous concentration [CC]" and 2) "the maximum concentration criterion [MC]". When metal ions occur in more than one valence state (see chromium) water quality criteria for separate valences are provided.

Aluminum [Al] {FL-1500 ppb in predominantly marine waters}: Aluminum values ranged from 270 in filtered water from Elevenmile Creek to 6,500 in unfiltered water from lower Perdido Bay. Of concern is that almost as much aluminum was detected in the filtered as unfiltered samples from Perdido River (in contrast to low concentrations in filtered water at other stations). Low pH of the river water (4.55 - 4.80) may make more aluminum available, in a dissolved state, in the

Table 7. Metal analyses for water samples from four locations in the Perdido Bay ecosystem, Alabama/Florida - 1989. Concentrations are expressed as nanograms/milliliter (ppb). UF = unfiltered sample, F = filtered sample.

	Perdido River		Elevenmile Crk		Lower Bay		Middle Bay	
Metal	UF	F	UF	F	UF	F	UF	F
Ag	<100	<20	<20	<20	<200	<200	<100	<200
Al	1,300	1,100	2700	270	6,500	<300	5,400	<300
As	1	<0.4	2.7	5	12	1	3.2	1
B	690	140	94	100	2,400	2,700	1,600	2,800
Ba	140	21	299	121	45	46	46	52
Be	<5	<1	<1	<1	<10	<10	<5	<10
Cd	<20	<2	<2	<2	<30	<20	<20	<20
Cr	<50	3	14	4	<100	20	<50	30
Cu	<10	3.2	13	0.9	<30	20	<10	20
Fe	1,400	830	10,400	130	3,400	<100	2,400	100
Hg	<0.3	0.3	<0.3	0.3	<0.2	<0.3	<0.2	0.5
Mg	294,000	29,600	11,100	3,410	894,000	720,000	620,000	695,000
Mn	83	49	1,330	170	730	40	65	50
Mo	<50	<10	<10	<10	<100	<100	<50	<100
Ni	<100	<20	<20	<20	<200	<200	<100	<200
Pb	<200	<40	<40	<40	<400	<400	<200	<400
Se	0.6	<0.3	0.3	1.3	0.4	0.3	<0.3	0.3
Sr	1,530	223	136	135	5,120	4,670	3,530	4,660
Tl	<300	<50	<40	<50	<600	<500	<300	<500
V	<20	<3	4	9.4	<30	<30	<20	<30
Zn	10	23	35	9.6	<20	<20	<10	<20

water column of the river. The aluminum is probably associated with organic acid molecules. The low pH is due to organic, rather than mineral activity. However, in the other samples most of the aluminum appears associated with particulate matter; i.e. clays, particulate organic matter, etc within the unfiltered samples. All filtered samples were well below State water quality criteria.

Arsenic [As] {FL-50 ppb} {EPA(AsIII)-FW 190 CC, 360 MC; SW 36 CC, 69 MC ppb}: Arsenic in the filtered samples was 12.5 times more abundant in Elevenmile Creek (5 ppb) than in Perdido River (< 0.4 ppb). The arsenic level in the filtered water sample from Elevenmile Creek also exceeded both Bay filtered water samples (1 ppb; 1 ppb) by a ratio of 5:1. However, all arsenic levels were well below State or EPA water quality criteria.

Beryllium [Be]: Beryllium was below detection limits in all water samples.

Cadmium [Cd]: Cadmium was below detection limits in all water samples.

Chromium [Cr] {EPA (CrIII)-FW CC 117, 984 MC ppb/SW none; (CrVI) FW-11 CC, 16 MC ppb/SW 50 CC, 1,100 MC ppb}: Chromium occurred in low concentrations in all filtered samples; (range 3 to 30 ppb).

Copper [Cu] {FL FW-hardness formula; predominantly marine, 2.9 ppb} {EPA FW- 6.54 CC, 9.22 MC ppb; SW- 2.9 CC, 2.9 MC}: In the filtered samples copper ranged from 0.9 to 20 ppb. The copper concentrations in the filtered water samples from both Bay stations (20 ppb each) exceed Florida water quality criteria.

Lead [Pb]: Lead was below detection limits in all water samples.

Mercury [Hg]: {FL FW- 0.012; predominantly marine- 0.025 ppb} {EPA FW- 0.012 CC, 2.40 MC ppb; SW- 0.025 CC, 2.1 MC ppb}: In the filtered freshwater samples mercury was detected at 0.3 ppb at both freshwater stations. In the filtered sample from the mid-Bay station, mercury was detected at 0.5 ppb. These values exceed Florida and EPA (continuous concentration) water quality criteria.

Nickel [Ni]: Nickel was below detection limits in all water samples.

Selenium [Se] {FL FW- predominantly fresh waters, 5 ppb; predominantly marine waters, 71 ppb} {EPA FW- 5 CC, 20 MC; SW 71 CC, 300 MC ppb}: All selenium concentrations were well below Florida or EPA water quality criteria.

Silver [Ag] {FL FW- predominantly fresh waters, 0.07 ppb; predominantly marine waters, 0.05 ppb} {EPA-FW 1.23 MC; SW 2.3 MC ppb}: Silver was below detection in all water samples. This is interesting because in our sediment survey silver was the only metal exceeding the probable effects level (PEL) of the sediment quality guidelines (SQG) (see sediment survey below). However, silver exceeded those levels only at the mouth of Saufley Field Ditch, (Station 4).

Thallium [Tl]: {FL FW & SW, 48 ppb}: Thallium was below detection limits in all water samples.

Zinc [Zn]: {FL FW- hardness formula; predominantly marine waters, 86 ppb} {EPA FW- 58.91 CC, 65.04 MC; SW 86 CC, 95 MC}: All freshwater samples were below Florida and EPA water quality criteria. All saltwater samples were below detection limits.

II. Organics Analyses, Group One - Organochlorine Pesticides and PCBs.

Water samples were analyzed for 21 organochlorine pesticides, isomers or break-down products. None were detected in any of the water samples (Appendix 1).

III. Organics Analyses, Group Two - Polycyclic Aromatic Hydrocarbons (PAHs).

Water samples were analyzed for 14 PAH compounds. None were detected in any of the water samples (Appendix 1).

SEDIMENT SURVEY

I. Introduction

The quality of the sediments of Perdido Bay has been studied and evaluated by a number of agencies and institutions (see Part Four). Major studies have been conducted by the Environmental Protection Agency (EPA), Florida Department of Environmental Regulation (FDER, now Florida Department of Environmental Protection), Fish and Wildlife Service (FWS), and Environmental Planning and Analysis Inc (EPAI) working with Tierra Consulting Company (TC).

The qualities of the sediments studied included physical and mineralogical nature characteristics (particle size distribution, clay mineralogy, etc), total organic carbon (TOC) content, metals, polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides (OCs) and polychlorinated biphenyls (PCBs). Dioxin compounds and dibenzofurans were also evaluated and are discussed in a separate section below.

II. Perdido Bay Sediment Stations

Over approximately the last ten years sediments have been collected for chemical analysis from over 300 sampling stations (Part Four, Table 5). The work has involved the efforts of both State governments, two Federal agencies and a number of private parties. The data gathered in these surveys should provide a valuable baseline for management of Perdido Bay as we enter the next century.

After inventorying the locations of previous sediment collection points, the Service determined that information was lacking for the bayous of Perdido Bay. The bayous are important receiving points for upland runoff or discharges from industrial, agricultural and urbanized areas. Therefore, to supplement, but not duplicate, sediment chemical data that already existed, sediment stations were primarily located in these information-deficient areas. A total of 20 sediment stations were sampled by the Service (Table 8 and Figures 3-6, Part Four).

III. Metals

Each sediment sample was analyzed for twenty-one metals. The laboratory data printout appears in Appendix 2. The metals included for analysis are listed below. Some metals have had an evaluation procedure developed for them and they are identified with an asterisk. Those procedures are either: a) an "aluminum:metal normalization" sample comparison test; or a "sediment quality guidelines (SQG)" sample comparison test.

The comparison procedures are discussed below. The suite of metals included:

Aluminum	*Copper	*Nickel
*Arsenic	Iron	Selenium
Barium	*Lead	*Silver
Beryillium	Magnesium	Strontium
Boran	Manganese	Thallium
*Cadmium	*Mercury	Vanadium
*Chromium	Molybdenum	*Zinc

Table 8. Fish and Wildlife Service sediment stations, Perdido Bay, Florida, 1989.

Station ID Number	Station Location	Latitude	Longitude	Depth (ft.)
PR-1	Perdido River (main channel)	30-27-24	87-24-97	19
PR-2	Perdido River (backwater)	30-27-68	87-24-81	4
PR-3	Elevenmile Creek (backwater)	30-27-61	87-22-67	4
PR-4	Saufley Field Ditch	30-27-08	87-21-54	3
PR-5	Bayou Marcus	30-25-57	87-20-21	8
PR-6	Bridge Creek	30-23-97	87-22-49	9
PR-7	Tarkiln Bayou	30-21-83	87-24-83	5
PR-8	Tarkiln Bay	30-20-77	87-25-13	9
PR-9	Bayou Garcon	30-19-04	87-26-13	6
PR-10	Old River	30-18-22	87-27-57	9
PR-11	Arnica Bay	30-18-25	87-31-82	12
PR-12	Lower Perdido Bay	30-20-14	87-28-21	12
PR-13	unnamed bayou Sec 13 R31W T2S (Pensacola Quad)	30-24-95	87-21-00	6
PR-14	Palmetto Creek (north end)	30-21-35	87-30-86	5
PR-15	Perdido Beach (in Palmetto Creek)	30-20-23	87-30-41	9
PR-16	Soldier Creek (north end)	30-22-01	87-30-02	7
PR-17	"Red Bluff" (in Soldier Creek)	30-20-62	87-29-56	10
PR-18	Kits Marina	30-24-11	87-26-14	7
PR-19	South of Nix Point	30-22-59	87-25-59	6
PR-20	Terry Cove (Sportsmans Marina)	30-17-15	87-33-07	12

All metal concentrations for sediments in this report are dry weight values in units of micrograms/gram (parts per million; ppm).

The first sample comparison procedure, developed by Schropp et al. (1990), normalizes a particular metal using aluminum as a reference element, and is based on State-wide (Florida) sampling from uncontaminated coastal sites. Any sediment sample can then be compared to a normalized aluminum to metal scale to interpret whether the metal concentration in the sample exceeds what would be expected to be a normal background concentration. The second procedure utilizes sediment quality guidelines developed by Long and Morgan (1990) and MacDonald (1993). The sediment quality guidelines (SQGs) include sediment metal concentrations likely to cause adverse biological effects. The Long and Morgan, and the MacDonald parameters are being employed in the EPAs Gulf of Mexico Sediment Inventory as their sediment quality guidelines. The following are the parameters developed for the SQGs:

<u>ER-L (Effects Range - Low):</u> A concentration of the metal in sediment at the low end of the range in which biological effects had been observed in scientifically controlled studies (Long and Morgan 1990).

<u>ER-M (Effects Range - Median):</u> A concentration of the metal in sediment approximately midway in the range of reported values associated with biological effects (Long and Morgan, 1990).

<u>TEL (Threshold Effects Level):</u> The concentration of a single chemical below which no biological effects would be expected (MacDonald, 1993).

<u>PEL (Probable Effects Level):</u> The concentration of a metal at which biological effects would nearly always be expected (MacDonald, 1993).

For metals without an associated methodology, available literature was reviewed and remarks and observations are included, as appropriate.

Table 9 presents the sediment_data results for the stations sampled. Metal concentrations at twelve of the twenty stations sampled (60%) did not exceed the criteria for either sediment test. Also, with the exception of one mercury value of 0.20 ppm (which just matched the TEL threshold criteria of 0.20) all bayous and side bays south of DuPont Point were scoreless for the tests used and the metals evaluated. However, the deep-water open bay station (Station 12) exceeded the test criteria for cadmium and mercury.

Elevenmile Creek was the most extensively sampled (seven separate stations). Each station had at least one metal that exceeded one of the comparison test criteria. The station furthest upstream from the mouth (the station at which sediments for the bioassay were collected) exceeded the aluminum:metal test for three metals; and exceeded the sediment quality guideline TEL concentrations for five metals. Furthermore, the mercury data (and the dioxin data below) appear to demonstrate (for the first three miles of Elevenmile Creek) that concentrations of mercury and dioxin generally increase in an upstream direction.

The only station with a metal value that exceeded a PEL criteria was Station 4, Saufley Field Ditch. Sediments collected from just inside the mouth of the ditch (composite sample; n=5) contained silver at 4 ppm, dry weight. Lead also exceeded the aluminum:metal confidence limits at Station 4.

At Bayou Marcus (Station 5) lead exceeded the aluminum:metals upper confidence limits. The TEL criteria were exceeded at this station for lead and mercury.

Stations 6 and 13, both near highway briuges, had somewhat elevated lead levels.

Station 19, south of Nix Point and offshore of the old seaplane ramps, exceeded the aluminum:metals confidence limits for cadmium, lead and zinc; and exceeded the TEL criteria for cadmium and mercury.

This sediment survey indicates that metal contamination problems exist in Elevenmile Creek, Saufley Field Ditch, Bayou Marcus, and south of Nix Point. Minor lead contamination occurs at the stations near highway bridges, i.e., at Station 6, Bridge Creek; and at Station 13, the unnamed bayou.

Table 9. Perdido Bay sediment stations with metal concentrations that exceeded either of the two sediment evaluation methodologies.

Station	Aluminum:Metal Test	Sed. Quality Guidelines
1. Perdido River	none	none
2. Perdido River	none	none
3. Elevenmile Creek	none	Hg-1.1
3a. Elevenmile Crk (bioassay sed.)	Cd-2.3; Cu-43; Zn-150	As-27; Cd-2.3; Cr-68; Hg-0.73; Zn-150
3b. DxSurv./EM1	none	Hg-0.26
3c. DxSurv./EM2	none	Hg-0.42
3d. DxSurv./EM3	none	Hg-0.69
3e. DxSurv./EM4	none	Hg-0.32
3f. DxSurv./EM5	Zn-132	Hg-0.97
4. Saufley Field Ditch	Pb-20	Ag-4.0*
5. Bayou Marcus	Pb-48	Pb-46; Hg-0.38
6. Bridge Creek	Pb-37	none
7. Tarkiln Bayou	none	none
8. Tarkiln Bay	none	none
9. Bayou Garcon	none	none
10. Old River	none	none
11. Arnica Bay	none	none
12. Lower Perdido Bay	none	Hg-0.27
12a. (bioassay sed.)	Cd-2.8	Cd-2.8; Hg-0.41
13. unnamed bayou	Pb-49	Pb-49
14. Palmetto Creek	none	none
15. Perdido Beach	none	none
16. Soldier Creek	none	none
17. Red Bluff	none	Hg-0.20
18. Kits Marina	none	none
19. south of Nix Point	none	Hg-0.22
19a. (bioassay sed.)	Cd-3.1; Pb-38; Zn-86	Cd-3.1;Hg-0.41
20. Terry Cove	none	none

*Exceeded the PEL concentration for silver of 2.5 ppm.

IV. Organic Compounds - Group 1, the Organochlorine Pesticides and PCBs.

Sediments were analyzed for the following organochlorine pesticides and total PCBs:

hexachlorobenzene	benzenehexachloride	oxychlordane
heptachlor epoxide	chlordane	trans-nonachlor
toxaphene	alpha-chlordane	dieldrin
endrin	mirex	cis-nonachlor
o, p' DDT	o, p' DDD	o, p' DDE
p, p' DDT	p, p' DDD	p, p' DDE
total PCBs		

Appendix 2 contains the laboratory organochlorine compounds data printout. Sediment quality guidelines exist for only seven compounds: the various forms of DDT (three); total DDT; chlordane; dieldrin and endrin. The analytical laboratory's lower level of detection for these compounds was 10 parts per billion (ppb); except that the detection limit for toxaphene and PCBs was 50 ppb. At these detection limits there were no organochlorine compounds identified in any of the sediment station samples.

E. Organic Compounds - Group 2, the Polycyclic Aromatic Hydrocarbons (PAHs).

Appendix 2 contains the laboratory PAH data for our sediment stations. PAH analyses included 14 compounds. These compounds are associated with various types of petroleum products. The PAH analyses included:

napthalene	fluorene	pyrene
anthracene	fluoranthrene	benzo(a)pyrene
1,2-benzanthracene	chrysene	
benzo(b)fluoranthrene	phenanthrene	
benzo(k)fluoranthrene	benzo(e)pyrene	
1,2,5,6-dibenzanthracene	benzo(g,h,i)perylene	

The analytical laboratory's lower level of detection for these compounds was 10 ppb. Sediment quality guidelines exist for twelve PAH compounds. Where guidelines existed, the results of our analyses were compared to them. The results of the sediment PAH analyses are presented in Table 10.

After evaluating the PAH data, the following observations can be made:

A) None of the individual or Total PAH sediment concentrations at any station exceeded the sediment quality guidelines.

B) The stations having the highest concentrations of Total PAHs (exceeding 300 ppb) were Saufley Field Ditch (670 ppb), Kits Marina (370 ppb), and unnamed bayou (360 ppb).

C) Samples were analyzed for 14 PAH compounds. The most compounds were detected at Saufley Field Ditch (14 of 14), Kits Marina (11 of 14), and unnamed bayou (10 of 14).

Table 10. Polycyclic aromatic hydrocarbon (PAH) analyses at 20 sediment stations in Perdido Bay, 1989. Concentrations are parts per billion (micrograms/kilogram) wet weight.

Station	PAH	PPB
1. Perdido River, main channel	fluoranthrene	10
	pyrene	10
	benzo(g,h,i)perylene	10
	Total	30
2. Perdido River, backwater	pyrene	10
	benzo(b)fluoranthrene	10
	Total	20
3. Elevenmile Creek	phenanthrene	20
	fluoranthrene	30
	pyrene	20
	benzo(b)fluoranthrene	10
	benzo(k)fluoranthrene	10
	benzo(e)pyrene	30
	benzo(a)pyrene	10
	1,2,5,6-dibenzanthracene	20
	Total	150
4. Saufley Field Ditch	napthalene	10
	fluorene	10
	phenanthrene	90
	anthracene	10
	fluoranthrene	120
	pyrene	140
	1,2-benzanthracene	20
	chrysene	30
	benzo(b)fluoranthrene	30
	benzo(k)fluoranthrene	20
	benzo(e)pyrene	60
	benzo(a)pyrene	60
	1,2,5,6-dibenzanthracene	10
	benzo(g,h,i)perylene	60
	Total	670
5. Bayou Marcus	fluoranthrene	50
	pyrene	20
	chrysene	20
	benzo(b)fluoranthrene	30
	benzo(k)fluoranthrene	10
	benzo(a)pyrene	10
	1,2,5,6-dibenzanthracene	20
	benzo(g,h,i)perylene	10
	Total	170
6. Bridge Creek	fluoranthrene	40
	pyrene	40
	chrysene	10
	benzo(b)fluoranthrene	20
	benzo(k)fluoranthrene	10
	benzo(e)pyrene	40
	benzo(a)pyrene	20
	1,2,5,6-dibenzanthracene	20
	benzo(g,h,i)perylene	40
	Total	240
7. Tarkiln Bayou	NO PAHs DETECTED	

Table 10. Polycyclic aromatic hydrocarbon (PAH) analyses at 20 sediment stations in Perdido Bay, 1989. Concentrations are parts per billion (micrograms/kilogram) wet weight.

Station	PAH	PPB
8. Tarkiln Bay	pyrene	10
	benzo(b)fluoranthrene	10
	benzo(g,h,i)perylene	10
	Total	30
9. Bayou Garcon	fluoranthrene	20
	pyrene	30
	benzo(b)fluoranthrene	10
	benzo(k)fluoranthrene	10
	benzo(e)pyrene	10
	benzo(a)pyrene	10
	benzo(g,h,i)perylene	20
	Total	110
10. Old River	fluoranthrene	10
	pyrene	10
	benzo(b)fluoranthrene	20
	benzo(k)fluoranthrene	10
	benzo(e)pyrene	10
	benzo(a)pyrene	10
	Total	70
11. Arnica Bay	benzo(b)fluoranthrene	10
	benzo(e)pyrene	10
	benzo(a)pyrene	10
	benzo(g,h,i)perylene	10
	Total	40
12. Lower Perdido Bay	NO PAHs DETECTED	
13. Unnamed bayou	phenanthrene	10
	fluoranthrene	40
	pyrene	70
	chrysene	10
	benzo(b)fluoranthrene	50
	benzo(k)fluoranthrene	10
	benzo(e)pyrene	60
	benzo(a)pyrene	50
	1,2,5,6-dibenzanthracene	10
	benzo(g,h,i)perylene	50
	Total	360
14. Palmetto Creek	benzo(g,h,i)perylene	10
	Total	10
15. Perdido Beach	benzo(b)fluoranthrene	10
	benzo(e)pyrene	10
	benzo(a)pyrene	10
	benzo(g,h,i)perylene	20
	Total	50
16. Soldier Creek	fluoranthrene	20
	pyrene	20
	benzo(b)fluoranthrene	10
	benzo(a)pyrene	10
	benzo(g,H,i)perylene	10
	Total	70

Table 10. Polycyclic aromatic hydrocarbon (PAH) analyses at 20 sediment stations in Perdido Bay, 1989. Concentrations are parts per billion (micrograms/kilogram) wet weight.

Station	PAH	PPB
17. Red Bluff	benzo(b)fluoranthrene	10
	benzo(e)pyrene	10
	benzo(g,h,i)perylene	10
	Total	30
18. Kit's Marina	phenanthrene	20
	fluoranthrene	10
	pyrene	120
	1,2-benzanthracene	20
	chrysene	40
	benzo(b)fluoranthrene	30
	benzo(k)fluoranthrene	10
	benzo(e)pyrene	50
	benzo(a)pyrene	10
	1,2,5,6-dibenzanthracene	20
	benzo(g,h,i)perylene	40
	Total	370
19. South of Nix Point	fluoranthrene	30
	pyrene	30
	1,2-benzanthracene	10
	chrysene	10
	benzo(b)fluoranthrene	10
	benzo(k)fluoranthrene	10
	benzo(e)pyrene	10
	benzo(a)pyrene	10
	benzo (g,h,i) perylene	30
	Total	150
20. Terry Cove	fluoranthrene	30
	benzo(e)pyrene	30
	1,2,5,6-dibenzanthracene	10
	benzo(g,h,i)perylene	30
	Total	100

D) The most commonly detected PAH compounds (and the number of stations at which they were detected) were benzo(b)fluoranthrene (15), benzo(g,h,i)perylene (14), pyrene (13), fluoranthrene (12), benzo(e)pyrene (11), and benzo(a)pyrene (11).

E) Only two stations were completely free of detectable PAHs. They were Station 7, Tarkiln Bayou, and Station 12, Lower Perdido Bay.

F) The data from the twenty stations that were evaluated appear to indicate that PAH contamination is only a minimal problem within the areas sampled.

CHEMICAL CONTAMINANT IMPACTS TO BIOTA

Three separate activities were undertaken to assess impacts to biota. First, fish tissues were analyzed for the presence of chemical residues. Second, a fish health assessment survey involving necropsies and histopatholocial examination was undertaken. Third, a ten-day bioassay using invertebrate organisms was conducted. Below are the results of those activities. Common names used for fishes are consistent with American Fisheries Society (1991) Special Publication 20.

A. Metals Analyses

The metals of primary concern are the heavy metals, cadmium, lead and mercury that have no known biochemical role in living organisms; and that have been documented to cause injury to biota under some conditions. Also of concern are metals such as arsenic and selenium; metals found in living organisms but known to be harmful in excessive amounts. Finally, the data were inspected for any abnormal concentrations of metals such as chromium, copper, nickel, zinc, etc. In the discussion below, all metal concentrations are micrograms per gram (parts per million) wet weight. Table (11) contains metal concentrations (ppm) for the turtle and fish species analyzed. The laboratory data appear in Appendix 3.

Arsenic

Low levels of arsenic (in a variety of arsenic compounds) normally occur in many animals. The levels observed in our samples fell within the range deemed to be background. The marine fish (gafftopsail catfish) had the highest concentrations (range=1.2 - 10.6). These values are normal for marine fishes. It is thought that arsenic is often elevated in marine biota because of their ability to accumulate this element from seawater or food sources (Maher, 1985). There is no evidence to indicate that the observed arsenic values are due to localized pollution. The great majority of the arsenic in marine organisms exists as water-soluble and lipid-soluble organoarsenicals. For most marine

I. Biota Chemical Residue Analyses

In 1989 and 1992, several fish species and one species of turtle were collected for residue analyses as follows:

1989

1) Female carp, composite sample (n=5), Elevenmile Creek. Tissues: muscle, ovarian.
2) Male carp, composite sample (n=5), Elevenmile Creek. Tissues: muscle, testicular.
3) Female gafftopsail catfish, composite sample-A (n=5), Hwy 98 bridge, Perdido Bay. Tissues: muscle, ovarian.
4) Female gafftopsail catfish, composite sample-B (n=5), Hwy 98 bridge, Perdido Bay. Tissues: muscle, ovarian.
5) Channel catfish, (n=1), Elevenmile Creek. Tissues: muscle, ovarian.

1992

1) White catfish, composite sample (n=10), Elevenmile Creek. Tissues: muscle.
2) Flathead catfish (n=1), Elevenmile Creek Tissues: muscle.
3) Female gafftopsail catfish, composite sample (n=10), near Inerarity Point, Perdido Bay. Tissues: muscle, ovary.
4) Male gafftopsail catfish, composite sample (n=10), outside mouth of Elevenmile Creek. Tissues: muscle.
5) Female spiny softshell turtle, individual samples (n=2), Elevenmile Creek. Tissues: muscle, liver, eggs.

Table 11. Metal concentrations (ppm) in three fish species and one turtle species collected in Elevenmile Creek and Perdido Bay, Florida.

Species/Tissue	Percent Moisture	As DW	As WW	Cd DW	Cd WW	Cr DW	Cr WW	Pb DW	Pb WW	Hg DW	Hg WW	Se DW	Se WW	Ni DW	Ni WW	Zn DW	Zn WW
Carp-1, muscle	78.9	.0	.0	.0	.0	.0	.0	.0	.0	.4	.1	2.0	.4	.0	.0	22	5
Carp-3, muscle	76.9	.3	.1	.0	.0	.0	.0	.0	.0	.4	.1	2.5	.6	.0	.0	21	5
Carp-2, ovary	70.7	.6	.2	.3	.1	4.0	1.2	.0	.0	.1	.0	3.5	1.0	.0	.0	583	171
Carp-4, testes	77.3	.7	.2	.0	.0	.0	.0	.0	.0	.0	.0	2.4	.5	.0	.0	88	20
White catfish 92, muscle	81.7	.5	.1	.0	.0	1.0	.2	.0	.0	.3	.1	3.2	.6	.0	.0	25	5
Channel catfish-9, muscle	80.4	.0	.0	.0	.0	.0	.0	.0	.0	.3	.1	1.5	.3	.0	.0	18	4
Channel catfish-10, ovary	60.9	.5	.2	.0	.0	.0	.0	.0	.0	.0	.0	4.1	1.6	.0	.0	110	43
Gafftopsail catfish-5, muscle	81.7	41.0	7.5	.0	.0	.0	.0	.0	.0	4.8	.9	1.0	.2	.0	.0	46	8
Gafftopsail catfish-7, muscle	78.9	50.0	10.6	.0	.0	.0	.0	.0	.0	4.4	.9	1.0	.2	.0	.0	72	15
Gafftopsail catfish-6, ovary	71.7	4.2	1.2	.0	.0	.0	.0	.0	.0	.8	.2	4.3	1.2	.0	.0	833	236
Gafftopsail catfish-8, ovary	74.1	7.1	1.8	.0	.0	.0	.0	.0	.0	1.5	.4	6.2	1.6	.0	.0	1,410	365
Gafftopsail catfish 92PB, muscle	78.2	53.2	11.6	.0	.0	.6	.1	.0	.0	4.2	.9	4.2	.9	.0	.0	42	9
Gafftopsail catfish 92EM, muscle	76.3	7.4	1.7	.0	.0	.0	.0	.0	.0	2.8	.7	5.2	1.2	.0	.0	41	10
Flathead catfish 92, muscle	77.3	.3	.1	.0	.0	.0	.0	.0	.0	.6	.1	2.3	.5	.0	.0	27	6
Spiny softshell turtle, EM1, muscle	81.6	.1	.0	3.1	.6	.8	.2	.0	.0	.4	.1	5.2	1.0	.0	.0	101	18
Spiny softshell turtle, EM1, liver	79.5	.3	.1	.0	.0	.7	.1	.0	.0	.8	.2	13.7	2.8	.0	.0	70	14
Spiny softshell turtle, EM1, eggs	70.6	.3	.1	.0	.0	.7	.2	.0	.0	.2	.1	6.4	1.9	.0	.0	76	22
Spiny softshell turtle, EM2, muscle	81	.4	.1	.9	.2	.7	.1	.0	.0	.3	.0	5.5	1.0	.0	.0	107	20

species there is general agreement that arsenic exists primarily as arsenobetaine, a water soluble organoarsenical that poses little risk to the organism or its consumer (Eisler 1988).

Cadmium

There is no evidence that cadmium is biologically essential or beneficial. Instead, it has been implicated as the cause of various deleterious effects in fish and wildlife (Eisler 1985). Cadmium was detected in only one fish sample, carp ovarian tissue at 0.1 ppm. Both turtles had some cadmium (0.2, 0.6 ppm) in the muscle tissue samples. Cadmium has been detected in some of the Service's Perdido Bay sediment samples, and Isphording (1988) has defined several large areas within the Bay where cadmium levels averaged 0.4 ppm. These concentrations, while detectable, are low and cadmium does not appear to constitute an environmental problem within the Bay.

Chromium

Chromium is known to be essential for normal metabolism in humans, mammals and other biological groups. However, in excess, particular types of chromium can have adverse effects on fish and wildlife (Eisler 1986). The carp ovarian tissue sample contained 1.2 ppm chromium. This metal was also detected in white catfish muscle (0.2) and gafftopsail catfish muscle (0.1). No other fish samples had detectable chromium. Trace amounts of chromium were found in the turtle tissues: muscle (0.1, 0.2), liver (0.1) and eggs (0.2). There is no evidence to indicate that the observed concentrations constitute a biological concern.

Lead

None of the biotic samples had detectable lead.

Mercury

Because of the toxic properties of methyl mercury in biological systems (Eisler 1987), the mercury data were of great interest. Mercury concentrations did not exceed any State of Florida fish consumption advisory levels *except for the muscle tissue (i.e., the edible fillet) of the gafftopsail catfish, where mercury concentrations were 0.9 ppm, wet weight, in each catfish sample.* The lower consumption advisory for mercury, in fish tissue, in Florida is 0.5 ppm wet weight. The gafftopsail catfish were the only fish that had mercury associated with their reproductive tissue. The two ovarian tissue samples had 0.2 and 0.4 ppm mercury, wet weight.

One turtle muscle tissue sample contained 0.1 ppm wet weight mercury, the liver was 0.2, and the turtle eggs contained 0.1.

Selenium

Selenium is an essential nutrient for some plants and animals. However, in excessive amounts selenium can cause injuries and has been shown to cause teratogenic problems (birth defects) (Eisler 1985). Selenium deficiency has also be reported among cattle grazing in the Florida Everglades. Under these conditions, the cattle showed evidence of anemia, slow growth, and reduced fertility (Morris et al., 1984). For many species of fish and wildlife proper amounts of selenium are necessary for normal metabolism and the selenium levels in the samples analyzed (fish and turtles), appeared to fall within normal ranges.

Nickel

There was no detectable nickel in any of the samples analyzed.

Zinc

Zinc is an essential nutrient and is only a problem for biological systems when it occurs in excessive amounts. Zinc plays important roles in cell differentiation and occurs in large concentrations in fish ovarian tissues (Eisler 1993). For the samples analyzed, zinc concentrations appeared to be within normal ranges.

B. Organic Compounds, Group One, the Organochlorine pesticides and PCBs.

Twenty-one organochlorine pesticides or their breakdown residues, and total PCBs were evaluated in muscle and reproductive tissue of three fish species: carp, channel catfish and gafftopsail catfish. (Appendix 4). In the great majority of the analyses (190 of 210) there were no organochlorine compounds present in concentrations exceeding laboratory levels of detection. Only three compounds were detected: total PCBs (seven of ten samples); p,p' DDE (five of ten samples); and trans-nonachlor (four of ten samples).

Polychlorinated Biphenyls (Total PCBs)

PCB compounds occurred in the carp muscle tissue at 90 ppb; in the ovarian tissue at 60 ppb; and in the testicular tissue at 50 ppb (wet weights). PCBs were not found in the channel catfish samples. The highest concentrations of these compounds occurred in the gafftopsail catfish collected in the bay. In muscle tissue of these fish PCBs were detected at 240 and 510 ppb. In ovarian tissue concentrations were 230 and 480 ppb. Because PCBs are ubiquitous in the environment, and gafftopsail catfish are fairly wide-ranging marine carnivores, it is impossible to determine the source or sources of PCB uptake for these fish. However, these tissue concentrations are in the low end of the range of fishes evaluated for PCBs throughout the United States, including coastal species (Eisler 1986) and there is no evidence to demonstrate that PCBs in Perdido Bay present a problem for fish and wildlife.

DDE

DDE is a breakdown product of a parent compound, DDT. Concentrations of p,p'-DDE were found in all four samples of the gafftopsail catfish. In the muscle tissue samples (n=2) concentrations for these fish were: 60 and 150 ppb. The ovarian tissue samples (n=2) contained 90 ppb each. In the channel catfish muscle tissue sample, p,p'-DDE was detected at 10 ppb.

trans-nonachlor

Concentrations of trans-nonachlor were only detected in gafftopsail catfish, and all four tissue samples had detectable amounts. Muscle tissue concentrations were 10 and 30 ppb. The ovarian tissue samples were each 10 ppb.

C. Organic Compounds, Group Two, the Polycyclic Aromatic Hydrocarbons (PAHs).

PAH compounds are an environmental concern in heavily contaminated areas because several of these compounds are known to be mutagenic, carcinogenic and teratogenic (Eisler 1987; Neff 1979, 1982). Fish tissues were evaluated for the same groups of PAH compounds identified in the sediments section of this study (page 83). However, the sensitivity of these fish analyses were limited because PAH compounds metabolize fairly readily in fish systems. If PAH compounds were identified as a significant contaminant in sediment or water samples in Perdido Bay, additional testing and analysis of fish liver bile would provide a better evaluation of the accumulation of these compounds in fish.

Of the 210 tissue analyses for PAHs, only 16 were positive, and at very low concentrations as follows: napthalene (2 samples), fluorene (4), phenanthrene (2), anthracene (1), pyrene (2), 1,2-benzeanthracene (1), benzo(b)fluoranthrene (1), and benzo(e)pyrene (3). Furthermore, 13 of the sixteen positive samples were just at the detection limit, 10 ppb wet weight. The only noteworthy observation was that the channel catfish collected in Elevenmile Creek had a "total PAHs" concentration of 130 ppb in the muscle tissue evaluated.

II. Fish Health Assessment

A. Fish Necropsies

In June and September, 1989, a total of 126 fish representing 25 species were collected from three locations. Common names used are consistent with the American Fisheries Society (1991).

The fish were collected for examination to determine the presence of any gross external or internal abnormalities. Station 1 (S1) included a stretch of Elevenmile Creek from approximately one mile above the mouth to 2.5 miles above the mouth. Station 2 (S2) was in the Perdido River in a similar stretch about one mile above the mouth. Station 3 (S3) was a marine station near the U.S. 98 highway bridge. Specimens were obtained from the Creek and River using electrofishing equipment, gill nets and trot lines. All fish collected in the Bay were obtained with gill netting. All fresh abrasions resulting from collection equipment were disregarded. Abnormalities in fish can include spinal column aberrations, pugheadedness and anomalies of the fins (Hickey 1972). Abnormal expression of secondary sex characters in mosquitofish (*Gambusia affinis*) from Elevenmile Creek has been reported by Howell et al. (1980) and laboratory induction of intersexuality has been demonstrated in mosquitofish exposed to effluent from the Creek (Drysdale et al., 1989). Davis and Bortone (1992) reported on masculinization of female poeciliid fish comparing two sites in

Florida (Elevenmile Creek and Fenholloway River) and noted development, by the females, of male secondary sex morphological characters (including modification of the anal fin into a gonopodium-like structure), concomitant with male fish behavior, including mating attempts.

General fish health was assessed following Goede (1989) and Hunn (1988). Most examinations were done in the field with fresh fish that had been placed on ice immediately after capture. However, some specimens had to be frozen in the field and examinations on these were done in the laboratory at the Panama City Field Office. Total weight, total length and fork length of each individual was recorded and in most cases a 35mm photograph of the specimen was taken prior to examination. Basic information about the fish collected for this survey can be found in Appendix 5.

External examination included inspection of the body form and surface, lips and jaws, snout, barbels, opercle, isthmus, eyes, fins, gills, pseudobranch, and urogenital/anus opening. Internal examination included inspection of the general body cavity, liver, gall bladder, stomach, pyloric caeca, intestines, spleen, gas bladder, kidneys, and testes/ovaries.

Station 1 - Elevenmile Creek

Sixty-four fish representing nine species were collected from this station; including 36 white catfish, 10 striped mullet, five channel catfish, six black crappie, three brown bullhead, one black bull head, one gizzard shad, one bluegill and one largemouth bass. All white catfish appeared normal. One individual had an internal parasite. All mullet were normal, with the exception of fin erosion on the left pectoral of one individual. Of the five channel catfish, one fish had inflammation or possible infection within the mouth; the others were normal. Of the three brown bullhead examined, the first individual appeared normal, the second had a papilloma on the upper lip and had no right pelvic fin, and the third had a papilloma on the top of the mouth. The largemouth bass had significant fin erosion on the caudal fin only. The black bullhead, gizzard shad and bluegill all appeared to be normal.

Station 2 - Perdido River

Only twelve fish were collected from the River even though considerable effort was expended gill netting, trotlining, and electrofishing. This collection included eight species, as follows; two channel catfish, three highfin carp sucker, two gizzard shad, and one each of the following; yellow bullhead, blacktail redhorse, spotted sucker, chain pickeral and flathead catfish. All fish appeared normal with the exceptions that: one channel catfish had an exopthalmic (bulging) eye; two of three carp suckers had papillomas; and the chain pickeral had a "white spot" within its eye.

Station 3 - Perdido Bay

Fifty fish were collected in the Bay near the U.S. Highway 98 bridge. This collection was composed of 12 species including: 14 gafftopsail catfish, eight hardhead catfish (sea catfish), eight pompano, four sheepshead, four southern flounder, two longnose gar, one spotted gar, one black drum, one blue fish, and one Atlantic stingray. The gar were concentrated at the surface of a gill net after a period of heavy rain. The marine fishes, particularly the bluefish and pompano were taken from the bottom of the gill net. Significant salinity stratification occurs near the bridge, even though the depth fished was only about eight to ten feet.

All fourteen gafftopsail catfish appeared normal. One hardhead catfish had a lesion on the stomach. All pompano were normal subadults; one individual had one pectoral fin much smaller than the other. All sheepshead appear normal, one individual had a small cyst in the left opercle. The black drum had fish lice ssociated with the left gill tissue. The bluefish was normal with the exception of a white discoloration on the lip.

CONCLUSIONS

Of the 126 fish examined, only 12 had abnormalities. These abnormalities included fin erosion (2), small papillomas (4), eye aberrations (2), oral inflammation (1), internal lesion (1), epidermal discoloration (1) and cyst (1). Of the 36 fish from Station 1 five had abnormalities (14%). There were 12 fish collected from Station 2 and four had abnormalities (33%). Finally the 50 fish from Station 3 included three individuals with abnormalities that might have been environmentally-induced. This survey was limited and the sample size (n=126) is not large given the overall geographic area of concern. Nevertheless, given the types of abnormalities observed, the rate of occurrence probably does not exceed what would be expected for wild populations of fish subjected to the various natural and anthropogenic stresses found in a modern coastal environment.

B. Fish Collections for Liver Histopathological Analyses

On October 19, 1989 the Service collected 48 individual fish of five different species from Elevenmile Creek. The species were white catfish (*Ictalurus catus*), channel catfish (*Ictalurus punctatus*), striped mullet (*Mugil cephalus*), black crappie (*Pomoxis nigromaculatus*), and largemouth bass (*Micropterus salmoides*). The liver tissues of these fish were microscopically examined by an EPA scientist at the Gulf Breeze, Florida laboratory. In general the fishes examined presented a picture of normal liver conditions for wild-caught fishes. However, the scientist suggested caution about drawing any final views on the general health of fish in Elevenmile Creek because the Service sample was relatively small and was taken only at one point in time. Seasonal conditions, environmental changes in the creek, and species behavior could influence, at anytime, the condition of fishes occupying the creek (Couch 1989). Results of the microscopic examination can be found in the EPA report dated November 29, 1989 (Appendix 6).

III. Ten-Day Toxicity Test

Perdido Bay Toxicity Study

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Local concern for the water quality in Perdido Bay has been stimulated by periodic or occasional die-offs of certain estuarine species, especially in the Upper Bay areas. As a result, citizen groups requested assistance in the evaluation of possible contaminant problems within the system. Most concerns were directed towards Champion International Corporation, owner of a bleached kraft paper mill on a tributary (Elevenmile Creek) to the Bay. In response to this request, the toxicity of water and sediments from Perdido Bay was evaluated in the fall of 1989.

Materials and Methods

Toxicity tests were conducted on water and sediments from Elevenmile Creek, Perdido River, Upper Perdido Bay, and Lower Perdido Bay, November 6 - 20, 1989 (see summary of tests conducted in Table 1). Hyalella azteca (Crustacea: Amphipoda) was used to assess the quality of water and sediment samples from freshwater

(Elevenmile Creek and Perdido River) sites. Hyalella azteca and Mya arenaria (Mollusca: Pelecypoda) were used in tests on water and sediments from the estuarine environment (Upper and Lower Perdido Bay).

Static-renewal tests and flow-through tests were conducted on water from all sites, and static tests were conducted on sediments from all sites. Flow-through tests were conducted on full strength and 50 % dilutions of water from the respective sites. Well water was used for the dilution water and control water for tests on samples from the freshwater sites. Gulf of Mexico water (30 o/oo [parts per thousand] salinity) was diluted with well water to 18 o/oo and used as control water and dilution water for the estuarine tests. The animals were exposed to the test matrices for a period of 10 days.

The apparatus used in the flow-through tests consisted of a head tank (6-L capacity) and a series (test replicates) of 10-glass beakers (250 mL) for each treatment. The beakers were positioned on a descending stair-step platform and water passed from one beaker to the next through a gravity-flow siphon system. Water from each sampling site (24-h composite sample collected with an ISCO water sampler) was collected on a daily basis and was used to replenish the water in the head tank as needed. Flow of water through the system was maintained at 5 mL/min.

Static-renewal tests were conducted in 250-mL beakers with 10 replicates for each treatment. Water was removed daily from each beaker using a suction device and then replaced with fresh test water.

Sediments were evaluated using static tests with 50-mL of sediment placed in each of 10 replicate 250-mL beakers for each study site.

Control water (150 mL) was carefully added so as to not disturb the sediment. The overlying water was aerated for 30 seconds daily to maintain dissolved oxygen concentrations above 6 mg/l.

Included in the tests with Hyalella were 10 pre-weighed leaf disks (blotted wet weights) that were used to measure feeding activity. After the termination of the test, leaf disks were retrieved, blotted dry and weighed. Differences between the pre- and post-weights provided a quantitative measure of feeding activity. Microtox bioassays were conducted on pore water extracted from the sediments from each site. The Microtox test measures the reduction of light emission from the test organism, a bioluminescent marine bacterium (Photobacterium phosphoreum). Effect Concentration (EC) is a measurement of the toxicity of a test solution to the bacterium. The EC50 and EC20 values are the concentrations of the test material (water or sediment pore water) that will produce the measured effect (EC). The effect that is measured is the inhibition of the bacterium's normal light production capability by 50% (EC50) and 20% (EC20) respectively. The more toxic the test solution, the greater effect observed and measured (reduction in light emission by the bacterium). Smaller EC values represent greater degrees of toxicity.

Pore water was extracted from the sediment using a syringe attached with airline tubing to a glass air stone. To extract the pore water, the air stone was inserted into the sediment sample and the syringe plunger was retracted and braced, forming a vacuum. The pore water accumulated in the barrel of the syringe. EC50s and EC20s of the pore water were calculated from light readings at the 5- and 15-minute time intervals. Results from the 15 minute readings contributed little to the toxicity information and were not included in the analyses.

capacity. During periods of rainfall, the water entering the Bay is acidic and low in alkalinity. Aluminum concentrations may become mobile and move into solution during these events. Concentrations of aluminum are high enough in the sediments (as they are in most sediments) to allow this to happen in the presence of low pH. This could have an influence upon estuarine organisms, particularly in the upper end of the Bay where water enters. A drastic change in the salinity of the water in the Bay system is associated with these hydrological events. A rapid shift in salinity from around 20 o/oo to essentially freshwater could have a major impact on truly estuarine species, such as clams that colonize the upper areas of the Bay during low rainfall periods. During the testing period in November, salinity decreased at mid Bay from 22 o/oo to less than 10 o/oo as a result of inflow caused by heavy precipitation.

The field toxicity tests on water and sediments suggest that there is somewhat reduced water quality, particularly at Elevenmile Creek and in Upper and Lower Bay, with Lower Bay appearing to be more impacted than Upper Bay (Table 9).
Residues of metals in sediments from Elevenmile Creek and Perdido Bay are consistent with these findings. The water and sediment quality are not extremely degraded in Perdido Bay, but conditions are bad enough to warrant concern and seek remediation.

samples aged over night. We do not know what is responsible for this toxicity, but contaminants or conditions causing this toxicity appear to be lost, altered or reduced during the aging process. Sediment pore water caused reductions in bacterial luminescence from all sites examined except from Perdido River and St. Andrews Bay (reference site). EC50s and EC20s (concentrations of treatment water that caused a 50 % or 20 % reduction in luminescence) suggest reduced quality of sediment-pore water from Elevenmile Creek and Perdido Bay.

The chemistry of the surface water tested is summarized in Table 6. The sediment pore water chemistry is summarized in Table 7.

Ammonia concentrations in pore water from Elevenmile Creek and Perdido River were higher than in pore water from Perdido Bay, but based on the pH of the water, concentration of the unionized ammonia (toxic form) would be below toxic levels.

Organochlorine pesticides, PCBs, petroleum hydrocarbons, and metals included in the water analyses were either at or near analytical detection concentrations or below levels known to pose environmental risk. The same was also true for sediment analyses, except some metal residues in sediments were higher than expected, particularly in Elevenmile Creek and Lower Perdido Bay (Table 8).

Mercury, arsenic, lead, zinc, cadmium, chromium and manganese were generally higher at Elevenmile Creek and Lower Perdido Bay than in sediments from the other sites and the controls.

A possible cause of water quality problems in Perdido Bay may be related to normal hydrological conditions that occur during periods of precipitation. The water discharging into Perdido Bay is very soft (low alkalinity) and essentially has no buffering

Results and Discussion

There were no significant differences in mortality of Hyalella in the flow-through tests on water from the freshwater sites (Table 2).

There were, however, significant differences between treatments and control in percent leaf material consumed and percent leaf consumed per animal per day. Feeding activity (measured as leaf material consumed per animal per day) was significantly higher in the control and the 50 % dilution from Perdido River water than in 100 % Perdido River water and the 100 and 50 % dilutions from Elevenmile Creek. This suggests that the water qualities of Elevenmile Creek and Perdido River were lower than the controls. Feeding activity appears to be a sensitive indicator of water quality when mortality is similar among treatments (water quality may not be toxic enough to cause mortality, but severe enough to elicit a behavioral response such as reduced feeding activity). When mortality is the same among treatments, feeding activity can be an effective measure of subtle impacts on behavioral activities. If mortality, however, is significantly different among treatments, feeding activity is a moot point and measurements are not statistically reliable because feeding activity is not independent from mortality.

The results from the static-renewal tests on water from Elevenmile Creek and Perdido River should be discarded because of the high mortalities of Hyalella in the controls caused by an inadvertent replacement of the water in the test beakers with estuarine (18 o/oo) water instead of fresh water on day three of the tests (Table 2). However, assuming that mortalities would have been below 10 % in the controls, mortalities in the Perdido River treatment (34 %)

would probably have been significantly higher than that of the control.

In the flow-through tests on estuarine water, Upper and Lower Bay samples were toxic to Hyalella (Table 3). Mortalities were higher in both the Upper (28 %)and Lower (24 %) Bay tests than in the control water (8 %), but the differences were not statistically significant. Percent leaf consumption per animal per day, however, was significantly higher in the control than in water from Upper and Lower Bay. These data suggest reduced water quality in Upper and Lower Perdido Bay.

Tests with Mya did not indicate water quality problems. Although mortality (20 %) of Mya from Upper Bay was higher than in control water and Lower Bay (0 %), these differences were not statistically significant.

Sediments from the freshwater sites were not toxic to Hyalella (Table 4).

Mortalities and leaf consumption between controls and freshwater treatments were similar. The same was true for mortalities in tests on estuarine sediments (Table 4). Feeding activity (percent leaf consumed per animal per day), however, was significantly higher in the control than in tests of sediment from Upper and Lower Perdido Bay, indicating reduced habitat quality for sediment in Perdido Bay. Mya did not indicate any toxicity in the sediments.

Pore water of sediments from Elevenmile Creek and Lower Bay was particularly toxic to luminescent bacteria used in the Microtox bioassays (Table 5). The toxicity was greatest on freshly extracted pore water, but this toxicity decreased noticeably on

Table 1. Summary of tests and test conditions used in the Perdido Bay Study, November 1989.

TEST MATRIX	TEST TYPE	TEST ANIMAL	TEST LENGTH	NUMBER OF REPLICATES	NUMBER OF ANIMALS/JAR
Freshwater	Static renewal	<u>Hyalella azteca</u>	10	10	5
	Flow through	<u>Hyalella azteca</u>	10	10	5
Estuarine water	Static renewal	<u>Hyalella azteca</u>	10	10	5
	Flow through	<u>Hyalella azteca</u>	10	10	5
	Static renewal	<u>Mya arenaria</u>	10	5	1
Freshwater Sediment	Static	<u>Hyalella azteca</u>	10	10	5
Estuarine Sediment	Static	<u>Hyalella azteca</u>	10	10	5
	Static	<u>Mya arenaria</u>	10	10	1
Sediment Porewater	Microtox	<u>Photobacterium</u>	5 min	-	-

Table 2. Effects of water and sediments from Elevenmile Creek, Perdido River, Upper Perdido Bay, and Lower Perdido Bay on survival and leaf consumption (with standard deviation) of <u>Hyalella</u> <u>azteca</u> during 10-day toxicity tests in November 1989. (Asterisks indicate significant difference with the control at $\alpha = 0.05$ using Dunnett's one-tailed T test).

Test Type/Location	Survival (%)	SD	Consumption (mg)	SD
Flow through-Fresh water				
Elevenmile Creek-100%	94	9.6	0.09*	0.03
Elevenmile Creek-50%	94	9.6	0.09*	0.03
Perdido River-100%	80	13.3	0.09*	0.03
Perdido River-50%	86	13.5	0.13	0.02
Freshwater control	86	13.5	0.13	0.02
Flow through-Estuarine				
Upper Perdido Bay-100%	72*	16.9	0.07*	0.01
Upper Perdido Bay-50%	84	15.7	0.08*	0.02
Lower Perdido Bay-100%	76	22.7	0.07*	0.02
Lower Perdido Bay-50%	82	11.3	0.06*	0.03
Estuarine Control	92	13.9	0.11	0.01
Sediment-Fresh water				
Elevenmile Creek	86	9.6	0.09	0.03
Perdido River	88	16.8	0.18	0.05
Fresh water control	88	13.9	0.11	0.03
Sediment-Estuarine				
Upper Perdido Bay	72	13.9	0.08	0.01
Lower Perdido Bay	54*	21.2	0.06	0.03
Estuarine Control	84	18.4	0.07	0.03

Table 3. Effects of water from Upper and Lower Perdido Bay on mortality and feeding activity of *Hyalella azteca*, and mortality of *Mya arenaria* measured during the Perdido Bay Study in November 1989.

Animal Test Value	Upper Bay 100%	Upper Bay 50%	Lower Bay 100%	Lower Bay 50%	Control Water	Instant Ocean Control
Hyalella azteca **Flow Through** % Mortality	28.0[a]	16.0[ab]	24.0[ab]	18.0[ab]	8.0[b]	8.0[b]
% Leaf consumed	5.1[bc]	5.7[abc]	4.9[c]	4.3[c]	7.4[a]	6.9[ab]
% Leaf consumed/animal/day	0.11[bc]	0.13[abc]	0.11[bc]	0.09[c]	0.15[a]	0.14[ab]
Static Renewal % Mortality	40.0[a]		50.0[a]		36.0[a]	46.0[a]
% Leaf consumed	4.3[b]		3.3[b]		8.1[a]	5.2[b]
% Leaf consumed/animal/day	0.11[b]		0.08[b]		0.21[a]	0.13[b]
Mya arenaria **Static Renewal** % Mortality	20.0[a]		0.0[a]		0.0[a]	0.0[a]

* Within each test (row), values with the same superscript are not significantly different.

Table 4. Effects of sediment from Elevenmile Creek, Perdido River, Upper Perdido Bay, and Lower Perdido Bay on *Hyalella azteca* and *Mya arenaria* measured during the Perdido Bay Study in November 1989.

Animal Measurement	FW Cont.	Eleven Mile Creek	Perdido River	SW Cont.	IO Cont.	Upper Perdido Bay	Lower Perdido Bay
Hyalella azteca % Mortality	12.0[a]	14.0[a]	12.0[a]	46.0[a]	16.0[b]	28.0[ab]	46.0[a]
% Leaf consumed	7.7[b]	6.5[b]	12.3[a]	7.3[a]	5.0[ab]	5.7[ab]	3.8[b]
% Consumed/animal/day	0.16[b]	0.13[b]	0.26[a]	0.20[a]	0.10[b]	0.12[b]	0.09[b]
Mya arenaria % Mortality				0.0[a]	0.0[a]	0.0[a]	0.0[a]

Within each test (row and sample matrix - freshwater and estuarine), values with the same superscript are not significantly different.

Table 5. Toxicity of pore water from sediments collected from Elevenmile Creek, Perdido River, Upper Perdido Bay and Lower Perdido Bay to Photobacterium phosphoreum using the Microtox bioassay.

Station	Extract	EC50	C.L.	EC20	C.L	R
Elevenmile:	Fresh	14.25	9.80 - 20.70	0.73	0.16 - 3.38	0.9876
		18.09	13.24 - 24.54	0.19	0.19 - 2.44	0.9918
		19.18	16.72 - 22.00	7.97	6.66 - 9.53	0.9984
	One day old	163.59	57.19 - 467.98	31.55	19.97 - 49.84	0.9994
		97.22	46.87 - 201.65	28.50	19.45 - 41.98	0.9996
		321.51	69.85 - 1479.8	83.87	37.46 - 186.4	0.9990
		90.03	72.01 - 112.00	24.94	22.23 - 27.84	0.9993
	Filtered Fresh	37.06	29.47 - 46.61	12.62	10.74 - 14.83	0.9978
Perdido River:	Fresh	NT		NT		
Upper Bay:	Fresh	57.32	12.25 - 268.00	27.36	10.00 - 20.00	0.9450
		99.10	0 - @	19.02	0.10 - @	0.8831
		NT		NT		
Lower Bay:	Fresh	0.71	0.23 - 2.19	0.03	0 - 0.28	0.9996
		3.11	1.03 - 9.37	0.15	0.01 - 2.69	0.9803
		41.57	27.98 - 61.76	3.03	1.67 - 5.43	0.9945
		9.38	5.62 - 15.66	1.55	0.40 - 6.01	0.9839
	One day old	73.12	3.76 - @	12.23	2.27 - 65.87	0.9901
		44.12	39.84 - 48.85	21.59	20.21 - 23.06	0.9999
	Five day old	57.85	4.70 - 710.50	29.71	7.15 - 123.38	0.9842
	Filtered fresh	13.99	12.10 - 16.19	2.72	1.90 - 3.89	0.9982
St. Andrews (REF):	Fresh	NT		NT		
Florisant control:	Fresh	125.00	90.00 - 174.00	31.00	28.00 - 35.00	0.9990

Table 6. Chemistry of water collected from Elevenmile Creek, Perdido River, Upper Perdido Bay, and Lower Perdido Bay Study in November 1989.

Station	Date	pH	Alkalinity (mg/l)	Hardness (mg/l)	Conduct (umhos)	Salinity (o/oo)	Ammonia (mg/l)
Elevenmile Creek	11/12	8.15	240	140	2600	1	2
	11/13	8.15	260	120	1550	1	2
	11/15	8.10	240	140	1600	1	2
	11/17	8.25	320	160	1600	1	2
Perdido River	11/12	4.65	0	300	1600	0	0
	11/13	4.55	0	20	90	0	0
	11/15	4.80	0	20	130	0	0
	11/17	4.70	0	20	180	0	0
Upper Perdido Bay	11/12	5.95	0		2500	2	0
	11/13	6.15	0		1900	1.5	0
	11/15	6.85	0		2400	2	0
	11/17	6.85	0		4800	3	0
Lower Perdido Bay	11/12	7.05	20		15000	10	0
	11/13	6.75	20		12000	8	0
	11/15	7.55	20		16000	12	0
	11/17	7.45	20		11000	8.5	0

Table 7. Chemistry of pore water extracted from sediments collected from Elevenmile Creek, Perdido River, Upper Perdido Bay, and Lower Perdido Bay as part of the Perdido Bay Study in November 1989.

Station	pH	Alkalinity (mg/l)	Conduction (umhos/cm)	Salinity (o/oo)	Ammonia (mg/l)	H_2S (mg/l)
Elevenmile Creek	8.35	300	650	0.5	28	0
Perdido River	8.25	380	10500	8	10	0.3
Upper Perdido Bay	7.90	220	18500	15.5	5	5
Lower Perdido Bay	8.20	280	25000	21	4	5
Florrisant Control	7.80	60	400	0	0	0
St. Andrews Bay (Ref)	7.65	140	30500	26	0	0

Table 8. Metal residues (ug/g dry weight) in sediments included in field toxicity testing at Perdido Bay, November 1989.

Element	Elevenmile Creek	Perdido River	Florisant Control	Upper Perdido Bay	Lower Perdido Bay	St. Andrews Control
Arsenic	27.0	2.4	7.8	14.0	15.0	9.2
Aluminum	12,000	7,800	4,800	16,000	11,000	12,000
Cadmium	2.30	1.10	0.85	3.10	2.80	2.30
Copper	43.0	12.0	9.0	19.0	17.0	9.0
Chromium	68.0	14.0	7.3	36.0	31.0	42.0
Lead	26.0	11.0	12.0	18.0	28.0	28.0
Manganese	270	23	730	170	380	170
Mercury	0.73	<0.11	<0.06	0.19	1.80	0.16
Molybdenum	8.7	4.7	<0.3	<0.3	<0.3	<0.3
Nickel	12.0	3.0	10.0	8.9	6.7	8.7
Selenium	0.40	1.30	1.70	0.68	0.41	1.10
Zinc	150	96	33	56	77	54

Table 9. Summary of toxicity testing results from the Perdido Bay Study in November 1989, with "X" indicating toxic response, and "." indicating no response.

Test/Organism/Parameter	Freshwater		Estuarine	
	Elevenmile Creek	Perdido River	Upper Perdido Bay	Lower Perdido Bay
Flow through Hyalella/Mortality	.	.	X	X[1]
Hyalella/Leaf consumption	X	X	X	X
Static renewal Hyalella/Mortality	.	.	.	.
Hyalella/Leaf consumption	.	.	X	X
Mya/Mortality			.	.
Sediments - Static Hyalella/Mortality	.	.	.	.
Hyalella/Leaf consumption	.	.	X	X
Mya/Mortality			.	.
Sediment Pore water Microtox/Luminescence	X	.	X	X

[1] Not statistically significant

IV. Perdido Bay/Elevenmile Creek Dioxin Investigations

A. Introduction

"Dioxin" is a general term for a number of related chemical compounds (polychlorinated-dibenzo-*para*-dioxins or PCDDs) having the same general structure. That structure consists of two benzene rings bonded together by two oxygen atoms. There are 75 potential variations to this molecular structure depending on the attachment of chlorine atoms at particular sites on each benzene ring (Figure 8). The position and number of chlorine atoms on the dioxin molecule is the factor that determines the particular toxicity of each configuration (Eisler 1986).

The most studied and most toxic form of dioxin is the molecule 2,3,7,8-tetrachlorodibenzo-*para*-dioxin; abbreviated 2,3,7,8-TCDD. The numbers in the name refer to the particular location of attachment for each of four chlorine atoms.

A closely related group of compounds that often occurs in environments where dioxin is found are the polychlorinated-dibenzofurans (PCDFs). These molecules are also extremely toxic and have molecular configurations very much like the dioxin molecule.

Dioxin is a chemical byproduct occurring at low concentrations during the manufacture of other compounds. It can be found in trace amounts in certain industrial air emissions or liquid effluents carrying industrial wastes. Some sources of dioxin include the manufacture of chemical pesticides, the most important of which is the herbicide 2,4,5-T (2,4,5-trichlorophenoxyacetic acid). In 1957, dioxin was identified by German chemists as a contaminant in the manufacture of trichlorophenol, a precursor of

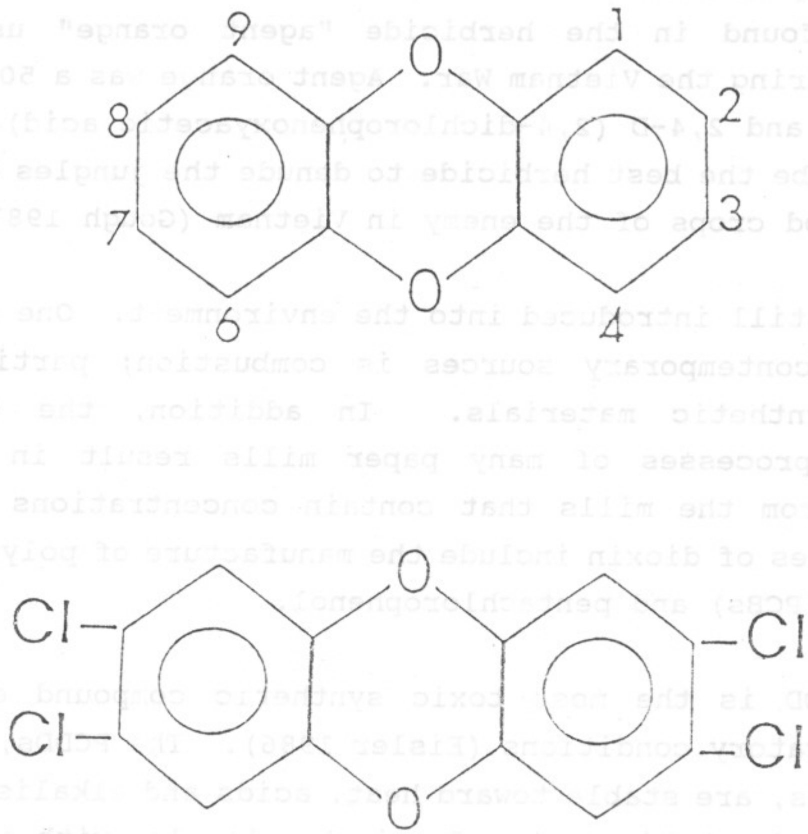

Figure 8. Upper. Numbering system used for identification of individual PCDD isomers. Lower. The isomer 2,3,7,8-tetrachlorodibenzo-para-dioxin (2,3,7,8-TCDD). Adapted from Eisler, 1986.

a variety of pesticides. The use of 2,4,5-T was suspended in 1979, and disappeared from United States commerce in 1983. However, prior to the ban, 2,4,5-T was used in large quantities. For example, in 1974 about 6 million pounds were used in the U.S. and probably as much as three times that amount worldwide. Dioxin was also found in the herbicide "agent orange" used by the military during the Vietnam War. Agent orange was a 50:50 mixture of 2,4,5-T and 2,4-D (2,4-dichlorophenoxyacetic acid). This was thought to be the best herbicide to denude the jungles and destroy certain food crops of the enemy in Vietnam (Gough 1987).

Dioxin is still introduced into the environment. One of the most important contemporary sources is combustion; particularly of modern, synthetic materials. In addition, the chlorinated bleaching processes of many paper mills result in industrial effluent from the mills that contain concentrations of dioxin. Other sources of dioxin include the manufacture of polychlorinated biphenyls (PCBs) and pentachlorophenol.

2,3,7,8-TCDD is the most toxic synthetic compound ever tested under laboratory conditions (Eisler 1986). The PCDDs, as a class of compounds, are stable toward heat, acids and alkalis. 2,3,7,8-TCDD is a hydrophobic (water-fearing) molecule, with a solubility in water of only 0.2 micrograms/liter (0.2 parts per billion). The PCDDs are chemically relatively stable and start to decompose only at temperatures greater than 500 degrees C or by photodegradation. None of the PCDDs have any known use. Few data exist in the literature that would indicate significant chemical and biological transformation of these compounds in aquatic or soil media. In aquatic media, PCDDs are primarily concentrated in the sediment-sorbed state or in biota. In mammals, 2,3,7,8-TCDD is readily absorbed through the gastrointestinal tract, and absorption through intact skin has also been reported. After absorption, 2,3,7,8-TCDD is distributed to tissues high in lipid (fat) content; however, in many species, the liver is a major storage site (EPA 1988).

Dioxin has its affect on living organisms at the cellular and subcellular levels. Although the biochemical processes are complex, a basic understanding of what happens at these biological levels is important to clearly understanding the real versus imagined threat of dioxin in the environment. First, there is no doubt that dioxin causes cancer in laboratory animals (Gough 1987). It is therefore a "carcinogenic" compound, at least to some forms of animal life. Dioxin can also be "teratogenic" (causing defects to developing embryos). It is not yet clear whether dioxin is "mutagenic" and can therefore cause damage (mutations) to the genetic material (contained in the chromosomes, and made up of deoxyribonucleic acid, or DNA) within an animal cell.

It is known that some of the dioxin isomers that have been studied negatively interact with a cellular enzyme system known as the "P-450 enzymes" by binding to a cellular protein called the Ah receptor. The chemical-Ah receptor complex then interacts with a specific location on the genetic material (DNA) to "turn on" the P-450 enzymes which, in turn, degrade or otherwise metabolize the foreign compounds. However, in certain animal cells (often in the liver) in which DNA has been previously altered (or "initiated") by a foreign substance, dioxin can accelerate the change of these cells into cancerous cells that multiply (Gough 1987).

Dioxin compounds can affect the early life stages of a fish (pike, *Esox lucius*) as has been demonstrated by Helder (1980). Helder observed retarded egg development and significantly retarded growth of fry. Test concentrations of 2,3,7,8-TCDD were from 0.1

to 10 parts per trillion. Highest mortality occurred during resorption of the yolk and reached almost 100% at 10 ppt. Edemas and hemorrhages were also observed along with alterations of blood vessel walls.

Because dioxin can significantly harm animal life, and because the Perdido Bay system could have received dioxin from several sources, it was important that an investigation of the situation be conducted. The Environmental Protection Agency took the lead in this investigation with other agencies and industries contributing valuable information. Although agricultural pesticides and atmospheric deposition may have contributed some dioxin to the area, it is generally agreed that a more certain source is the industrial effluent of Champion International Corporation that flows into Elevenmile Creek.

Primarily because of the potential impact to human health, and because of impacts to fish and wildlife resources, a program was established by the EPA to evaluate levels of dioxin in the edible portions and whole bodies of several species of fishes. Fish were collected from Elevenmile Creek, the mouth of the Perdido River, and in Perdido Bay. Some of the fish samples were collected by contractors for EPA. These samples were part of the National Dioxin Study - Bioaccumulative Pollutant Study. Other fish were collected under EPA direction by contractors working for Champion International Corporation. Due to the results of these analyses, a health advisory about consumption of fish from Elevenmile Creek was posted (Florida Department of Health and Rehabilitative Services 1990), However, in subsequent fish analyses, only low concentrations of dioxin were detected. The latter data resulted in a lifting of that advisory.

B. Environmental Protection Agency Dioxin Data

In 1990, the EPA established a recommended maximum level of dioxin in fish at 7 ppt. Federal Food and Drug Administration policy states that dioxin levels below 25 ppt are acceptable (Florida Department of Health & Rehabilitative Services 1990). EPA dioxin data for Perdido Bay can be found in Appendix 7.

C. Champion International Corporation Dioxin Data

Under Section 308 of the Clean Water Act, 33 U.S.C., Section 1318, EPA required on June 24, 1988 ,and January 23, 1989, that Champion International Corporation submit a plan of study and undertake a sampling program to monitor dioxin in various media (Barrett 1988) (Barrett 1989). Those media included fish, shellfish, sediment, and effluent. Dioxin data provided to the Service by Champion International can be found in Appendix 8.

1. Water Samples

Final mill effluent dioxin and furan concentrations for 1990 were measured three times during that year. Results were non-detect at detection limits as low as 1.5 parts per quadrillion.

2. Sediment Samples

Sediment samples were collected from transects chosen at Sites III and IV on June 13, 1989. A KB™ core sampler was used to sample sediment. Of five sediment samples, four were non-detect for 2,3,7,8-TCDD. One station had a concentration of 10.8 ppt (Site II [Elevenmile Creek], sample collection number CH-3-II-SD-II1).

3. Fish Samples

Champion evaluated dioxin concentrations in fish from collections made on February 5-9, 1990, and May 6-8, 1991. Data provided by Champion International for these analyses can be found in Appendix 8. Speckled trout from the 1990 collection were re-analyzed because initial results were questioned.

Fish were collected from five sampling sites in 1990. Eight species of fishes were analyzed. 2,3,7,8-TCDD was detected (ppt) in the fish fillets of four species: bluegill (1.2 - 4.3); white catfish (8.5 - 11.4); hardhead catfish (non-detect - 0.53); and mullet (non-detect - 0.74).

Also in the 1990 collection, 2,3,7,8-TCDF was detected (ppt) in the fish fillets of seven species: bluegill (0.60 - 0.71); warmouth (0.61); white catfish (non-detect - 0.37); hardhead catfish (non-detect - 0.16); mullet (non-detect - 2.0); speckled trout (non-detect - 0.52); and sheepshead (non-detect - 0.18).

Champion International Corporation requested that ENSR Consulting and Engineering obtain fish samples from Elevenmile Creek and analyze them for the presence of dioxin in fish tissues (ENSR 1991). As a result, in 1991 fish were collected from three sampling sites. Five species of fish were analyzed including bluegill, yellow bullhead, catfish (channel catfish and white catfish), Atlantic croaker, and mullet. All samples were non-detect for 2,3,7,8-TCDD except for two species. In the fillets of the catfish composite sample (n=3) 2,3,7,8-TCDD was detected at a concentration of

0.99 ppt. In the mullet fillets (n=5) 2,3,7,8-TCDD was detected at 0.42 ppt.

Also in the 1991 collection, 2,3,7,8-TCDF was detected in one species. The bluegill fillets had concentrations ranging from 0.31 - 0.37 ppt.

D. Fish and Wildlife Dioxin Evaluation

In May and July 1992, sediment, fish, and reptile samples were collected from Elevenmile Creek and Perdido Bay for analysis of dioxin and furan compounds. Background data related to those collections can be found in Appendix 9.

SEDIMENT EVALUATIONS

In May 1992 sediment samples were collected from five locations in or near Elevenmile Creek. Station locations can be found in Table 12. Sediment samples were obtained with a stainless steel ponar grab and handled in accordance with the standard operating procedures described in Appendix 10. Sediment particle size information is also provided for each sample in Appendix 11. Laboratory quality control/quality assurance criteria and analytical procedures can be found in the Data User Manual (Triangle Laboratories 1992) (see also Appendix 14).

Table 12. Dioxin Sediment Sampling Stations, Elevenmile Creek, Escambia County, Florida.

Sediment Stations (n=5) Station	Latitude	Longitude	Distance from Creek Mouth (miles)
EM-1	30° N 27′ 12″	87° W 22′ 35″	-0.1*
EM-2	30° N 27′ 22″	87° W 22′ 39″	0.1
EM-3	30° N 27′ 42″	87° W 22′ 37″	0.7
EM-4	30° N 28′ 02″	87° W 22′ 04″	1.7
EM-5	30° N 28′ 14″	87° W 21′ 58″	2.2

*Outside of Creek mouth in Perdido Bay.

The toxicity equivalents (relative to 2,3,7,8-TCDD) were calculated for each sediment station (Appendix 9) using Toxicity Equivalency Factors (TEFs) in accordance with the EPA-1989/NATO TEFs developed by the Environmental Protection Agency (EPA/625/3-89/016; March 1989). Only absolute laboratory-detected sample concentrations were used to calculate the toxicity equivalents.

The laboratory data for the sediment samples can be found in Appendix 12. Table 13 summarizes the toxicity equivalent data for the five stations.

As indicated by Table 13, dioxin concentrations generally increased in an upstream direction in backwater silt/clay/organic sediment areas. Because the furthest upstream station was only about two miles above the Creek mouth, other backwater areas further upstream could have sediments with considerable dioxin concentrations.

Table 13. Dioxin toxicity equivalents for five sediment stations in or near Elevenmile Creek, Perdido Bay, Escambia County, Florida.

Sediment Stations	Distance from Creek mouth	Toxicity Equivalent (ppt)
EM-1	-0.1*	17.7
EM-2	0.1	25.8
EM-3	0.7	51.2
EM-4	1.7	38.5
EM-5	2.2	78.4

*Outside of Creek mouth in Perdido Bay

EVALUATIONS OF BIOTA

Two freshwater species of fish (flathead catfish, white catfish) and one species of reptile (spiny softshell turtle) were collected from Elevenmile Creek; and one marine fish species (gafftopsail catfish) was collected from two locations in Perdido Bay (Table 14).

Table 14. Dioxin Fish and Wildlife Sampling Stations, Elevenmile Creek, Escambia County, Florida.			
Sediment Stations (n=5) Station	Latitude	Longitude	Distance from Creek Mouth (miles)
EM-FC[1]	30° N 28′ 06"	87° W 22′ 05"	2.1
EM-WC[2]	30° N 28′ 06"	87° W 22′ 05"	2.1
PB92-2[3]	30° N 21′ 30"	87° W 25′ 30"	N/A
PB92-3[3]	30° N 27′ 12"	87° W 22′ 30"	-0.1
EM-T1[4]	30° N 28′ 14"	87° W 21′ 58"	2.2

1 Flathead Catfish *Pylodictis olivaris* (n=1)
2 White Catfish *Ameiurus catus* (n=10)
3 Gafftopsail Catfish *Bagre marinus* (n=10; n=10)
4 Spiny Softshell Turtle *Trionyx spiniferus* (n=2)

Specific information about each sample is provided in the dissection reports found in Appendix 13. Biological samples were collected using electrofishing apparatus, gill nets, and trot lines. All samples were placed immediately on ice in thermal coolers, frozen in the field within four hours of capture, and prepared for shipment upon return to the Panama City Field Office. Some samples were composites of ten individuals and others were single individuals. One or more tissues from each species were analyzed for the presence of dioxin compounds. Tissue samples were shipped to the same analytical laboratory as were the sediment samples and the same sample quality control/quality assurance procedures were followed.

Tissue samples were shipped to the laboratory in certified, chemically-clean glass jars with teflon-lined lids. Toxicity equivalents were calculated as described in the sediment section above. Table 15 summarizes the dioxin toxicity equivalent data for the specimens collected.

Table 15. Dioxin toxicity equivalents for six biological samples collected from Elevenmile Creek or Perdido Bay, Escambia County, Florida.

Species	Sample Identification	Location	Toxicity Equivalent
flathead catfish	EM-FC (n=1)	2.1 miles from mouth	0.02
white catfish	EM-WC (n=10)	2.1 miles from mouth	0.02
spiny softshell turtle	EM-T1 (n=1)	2.2 miles from mouth	35.42
spiny softshell turtle	EM-T2 (n=1)	2.1 miles from mouth	17.50
gafftopsail catfish	PB92-2 (n=10)	Inerarity Point	0.02
gafftopsail catfish	PB92-3 (n=10)	at mouth of Creek	0.17

Examination of Table 15 reveals that while the fish species sampled were relatively free of dioxin compounds, based on the turtle data, other species of wildlife may be living some risk, either as individuals or populations.

E. Service Observations And Recommendations Related To Dioxin In Perdido Bay/Elevenmile Creek

1. Observations:

a) Existing final effluent data provided by Champion International Corporation indicates that concentrations of dioxin in that effluent are below detection.

b) Service data and Champion data for sediments indicate that backwater areas in Elevenmile Creek have become significantly contaminated with dioxin compounds, in particular 2,3,7,8-tetrachlorodibenzodioxin. The geographic extent of the contamination and maximum levels of contamination are unknown.

c) Little sediment sampling for dioxin has been done in Perdido Bay proper, but the one station sampled outside the mouth of Elevenmile Creek was contaminated.

d) Based on the dioxin residues in the turtles, long-lived resident species using Elevenmile Creek may be at some, as yet unquantified, risk to either individual animals or local populations.

e) Most fish species within Elevenmile Creek do not currently appear to be accumulating dioxin above EPA or FDA concern levels. However, nothing is known about potential subtle impacts of dioxin to reproduction or to the survival of the fishes in the Creek.

f) Dioxin impacts to other species inhabiting the Creek, such as invertebrates, birds, and mammals are unknown.

2. Recommendations:

a) Further sediment sampling for dioxin should be conducted in additional backwater areas of Elevenmile Creek to evaluate the total geographic extent and maximum contamination levels of dioxin within the system.

b) Sediment sampling for dioxin should be conducted at depositional areas in Perdido Bay, particularly the deepest areas of the Bay between the Highway 98 bridge and Inerarity Point, to assure that those areas are free of dioxin contamination.

c) Further evaluations should be conducted to assess the health of additional wildlife species using Elevenmile Creek, its wetlands, floodplain, and adjacent uplands. This work should include additional chemical analyses for dioxin compounds.

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