NOAA Technical Memorandum NOS OR&R 5

LCP Chemical Site Monitoring Study

Data Report

Seattle, Washington
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National Ocean Service

Office of Response and Restoration
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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NOTICE

Executive Summary

A monitoring study was conducted at the LCP Chemical site in Brunswick, Georgia with the following objectives:

1) Examine the bioavailability of mercury, methylmercury, lead, and PCBs in transplanted oysters and in three resident species located near the LCP site relative to uptake at a reference location. Relationships among concentrations in sediment, surface water, and tissues will be examined to assess correlations among the matrices. Bioaccumulation in deployed and resident oysters will be compared to verify that deployed oysters are appropriate surrogates to evaluate bioavailability at the site.

2) Provide a characterization in order to assess the success of the upcoming removal action to be taken in the marsh. A trend analysis will likely need to be conducted to determine if tissue concentrations are decreasing over time to acceptable concentrations.

3) Determine the extent and magnitude of contamination remaining in the marsh after completion of removal actions in the upland portions of the site. Contamination gradients from the area previously identified as a major source of contamination will be examined.

The sampling in this study included the collection of sediment, water, fish (*Fundulus heteroclitus*), fiddler crabs (*Uca* spp.), resident oysters (*Crassostrea virginica*), and deployment of caged oysters for chemical analysis at the same stations along a gradient away from the area of known contamination at the site, and at three stations in tributaries in the marsh, and at two reference stations for comparison purposes.

Conclusions include:

1) Mercury and Aroclor 1268 are bioavailable throughout the site and are present at elevated concentrations (relative to the reference area) in water, sediment and all three species of biota tested in this study. Biota concentrations correlate well with water and sediment concentrations indicating that water and suspended sediments may be a significant pathway for spreading mercury contamination throughout the site. Caged oysters appear to be reasonable surrogates for resident oysters.

2) The analysis of contamination in sediment, water, *Fundulus*, fiddler crab, and oysters are effective measurements for monitoring contamination at the LCP site. These measurements should be repeated to document the success of removal actions at reducing exposure of contaminants to site biota.

3) Considering the former outfall ditch as the primary source of contamination to water, sediment, and biota can adequately explain the observed patterns of contamination. Based on differences between creek bottom and creek bank sediment, it appears that methylation may be occurring at a greater rate on the marsh surface than in creek sediments.

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1 Introduction and Objectives

The LCP Chemical site is adjacent to the Turtle River in Brunswick, Georgia. The property covers about 220 hectares, about 190 hectares of which are unmanaged tidal wetlands. The LCP site includes much of Purvis Creek and numerous small tributaries discharging to this creek. The tidal range in the area is approximately 2 meters. Salinity in the area ranges from 0 to 32 ppt. The site was used by Atlantic Richfield Company as a petroleum refinery from 1919-1930, and was purchased by Georgia Power in the mid-1930's. Operation of a chlor-alkali operation run by Allied Signal Corp (then Linden Chemical and Plastic Corp.) between 1955 to 1994 is also a source of contamination at the site. The primary contaminants of concern at the site are mercury, PCBs (particularly Aroclor 1268), and lead.

Previous sampling of biota at the site documented elevated concentrations of mercury and PCBs in *Fundulus heteroclitus* and fiddler crabs (*Uca* spp.). Maximum concentrations of total mercury and Aroclor 1268 in *Fundulus* were as high as 5.5 and 320 mg/kg (dry weight) respectively. Maximum concentrations of mercury and Aroclor 1268 in fiddler crabs were 4.1 and 78 mg/kg (dry weight). These concentrations indicate that a risk may be posed to aquatic organisms and higher level consumers such as birds (Sprenger et al., 1997). These results warrant the evaluation of sediment, surface water, and biota at the site to establish a basis for measuring the extent that risk from exposure to mercury, PCBs, and lead has been reduced following recently undertaken and planned removal actions.

This monitoring study included an *in situ* Eastern oyster (*Crassostrea virginica*) transplant study, in addition to collection and analysis of resident Eastern oysters, *Fundulus heteroclitus*, fiddler crabs (*Uca* spp.), sediment, and surface water.

Sampling was conducted during the summer of 1997 after upland removal actions were completed but prior to the start of a new phase of planned removal actions for the marsh areas. Removal of sediment is currently being undertaken in the LCP ditch, tributary, and marsh area indicated on Figure 2.1. This study provides data to determine the extent of bioavailability of mercury, PCBs, and lead in the LCP Ditch, Purvis Creek, and in the marsh bordered by Purvis Creek and the LCP facility (south of the causeway) by measuring uptake in deployed and resident organisms.

The goal of this monitoring is to provide information useful to document the success of removal actions at reducing imminent and substantial threats to the environment and to determine whether further unscheduled removal actions may be warranted. A secondary goal of this monitoring is to provide a basis of information that will be consistent with future needs. It is anticipated that the data collected through this effort will be consistent with subsequent efforts directed by EPA Region IV's Remedial Program. The monitoring study was designed to meet the following specific objectives:

1) Examine the bioavailability of mercury, methylmercury, lead, and PCBs in transplanted oysters and in three resident species located near the LCP site relative to uptake at a reference location. Relationships among concentrations in sediment, surface water, and tissues will be examined to assess correlations among the matrices. Bioaccumulation in deployed and resident oysters will be compared to verify that deployed oysters are appropriate surrogates to evaluate bioavailability at the site.

2) Provide a characterization in order to assess the success of the upcoming removal action to be taken in the marsh. A trend analysis will likely need to be conducted to determine if tissue concentrations are decreasing over time to acceptable concentrations.

3) Determine the extent and magnitude of contamination remaining in the marsh after completion of removal actions in the upland portions of the site. Contamination gradients from the area previously identified as a major source of contamination will be identified.

2 Methods

2.1. Overview

The sampling in this study included the collection of sediment, water, fish (*Fundulus heteroclitus*), fiddler crabs (*Uca* spp.), resident oysters (*Crassostrea virginica*), and deployment of caged oysters for chemical analysis at the same stations along a gradient away from the area of known contamination at the site, at three stations in tributaries in the marsh, and at two reference stations for comparison purposes. Sampling was conducted between July 29, 1997 and August 26, 1997. Sediment, water, resident oysters, fiddler crabs, and most of the fish were collected between July 29 and August 2, 1997. Additional fish were collected on August 25 and 26, 1997. Caged oysters were deployed on August 1, 1997 and retrieved on October 1 and 2, 1997.

Eight site-related stations were sampled in the Purvis Creek system (Figure 2.1): one in the creek undergoing removal actions, one in the LCP Ditch, one at the mouth of the LCP ditch where it joins Purvis Creek, one in each of three tributaries that drain the wetlands to the south of Purvis Creek, one at the mouth of these tributaries where they join Purvis Creek, and one near where Purvis Creek joins the Turtle River. In addition, two reference stations were sampled (Figure 2.2). These were located in the Crescent River near Crescent, GA, 2.6 km south of the Sapelo River and were selected to be similar to site stations based on marsh vegetation and physical parameters of tributary size, approximate salinity, tidal flow, water depth, and sediment grain size.

The first reference station, Station 1, serves as a reference area for upstream stations at the site that are exposed during low tide or are under shallow water (stations 3, 4, 6, 7, and 8). The second, Station 2, is a reference for the areas in Purvis Creek that are not exposed to air during low tide conditions or are under deeper water (stations 5, 9 and

10). These two reference stations should also control for the temperature conditions present in the different areas.

Table 2.1 summarizes sample station locations. Table 2.2 lists samples collected for this study. At each station three replicate oyster cages were deployed. Three sediment samples were collected from the creek bottom at each cage location to represent sediment to which oysters are exposed, for a total of nine sediment samples per station. Only three of the sediment samples were immediately analyzed. The remaining six sediment samples were archived. Two surface water grab samples, one each at high and low tide, were collected at the center of each oyster deployment station for analysis to represent surface water to which oysters are exposed (Figure 2.3). Both filtered and unfiltered water samples were analyzed. During low tide the caged oysters at stations in the LCP Ditch and the tributaries discharging to Purvis Creek were exposed to air.

Resident oysters were collected at three site-related creek stations: one station in the LCP ditch (station 4), one station where the LCP ditch joins Purvis Creek (station 5), and one station near where Purvis Creek joins the Turtle River (station 10).

Resident fish (*Fundulus*) were collected at each station. Three replicate composite samples were analyzed at stations where sufficient fish were collected. Additional tissue samples were collected when available and archived. Fiddler crabs (*Uca* spp.) were collected from the creek banks adjacent to oyster deployment and fish collection stations. At each of the fiddler crab sampling stations, fiddler crabs were collected and composited to yield three composite samples where sufficient crabs were collected. At each crab collection station, three creek bank sediment grab samples were collected and composited to represent sediment to which crab are exposed, for a total of nine creek

bank sediment samples per station. Only three of these samples were immediately analyzed, the remainder were archived.

2.2 Sampling Methods

Decontamination of all sampling equipment was conducted between sampling at each sampling station. All equipment was rinsed with tap water, washed vigorously with a brush and alconox, rinsed with tap water, then rinsed with deionized water, and wrapped in aluminum foil.

2.2.1 Water Collection

Between July 29 and July 31, 1997, water samples were collected from all stations. Water samples were collected within one hour of both high and low tide over the central oyster deployment location at each station. One water sample was collected at each tidal stage at each station. Water was collected directly into pre-cleaned and pre-labeled jars provided by the chemical analysis laboratory. Each jar was submerged approximately 30 cm below the surface of the water, the cap was removed, the jar was filled, the cap replaced underwater, and the jar was placed in a cooler and chilled until it was shipped by overnight courier to the chemical analysis lab. Water was filtered at the chemical analysis laboratory. All unfiltered water samples were analyzed for total mercury, lead, PCBs, iron, manganese, ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, total suspended solids. Filtered water samples were analyzed for total mercury, lead, iron, manganese, and dissolved organic carbon. Filtered and un-filtered water samples taken at low tide from stations 5, 9, and 10 were also analyzed for methylmercury.

2.2.2 Sediment Collection

Between July 29 and July 31, 1997, sediment was collected from eight stations in the marsh and both reference stations. Both creek bottom and creek bank sediment samples were collected using a decontaminated 0.1 m^3 petite ponar grab. At each

station, three creek bottom sediment stations were located 5 m apart at the locations where oyster cages would later be deployed. Three creek bank stations were located over the area where fiddler crab samples were taken, on one bank, adjacent to creek bottom sampling stations. At each sampling location, the top 10 cm of sediment was collected using the grab, the grab was checked to make sure it had deployed properly (jaws closed, no debris protruding from jaws), the grab was then emptied into a decontaminated stainless steel bowl. Between one and three grabs were required to fill a bowl. Sediment was thoroughly mixed using a decontaminated stainless steel spoon. Pre-labeled glass jars provided by the chemical analysis laboratory were filled using the same spoon. A total of nine creek bottom and nine creek bank sediment samples were collected at each station. All samples were chilled in ice-filled coolers until they were shipped by overnight courier to the chemical analysis lab or to the EPA Region IV Environmental Services Division facility in Athens, GA for archival. Three creek bottom samples and three creek bank samples per station were analyzed for total mercury, lead, Aroclor 1016, 1221, 1232, 1242, 1248, 1254, 1260, and 1268, sulfides, grain size, total organic carbon, and moisture content. One creek bottom and one creek bank sediment sample from the center of each station were analyzed for methylmercury.

2.2.3 *Fundulus* Collection

Between July 29 and August 2, 1997 *Fundulus* were collected at seven of the eight stations in the marsh (all stations except station 9) and at both reference stations. Only one fish was collected at station 10 during this period. On August 25 and 26, 1997 additional fish were collected at stations 9 and 10.

At each station, a one-inch diameter PVC pole was driven into the sediment to mark the center of the station and attach minnow traps. Three decontaminated minnow traps

were baited with hot dogs and tied to the pole with a nylon line. Traps were placed so that they would remain submerged at low tide. Traps were checked between tidal cycles. Fish were placed in decontaminated plastic buckets containing 10 L of site water. Fish were held in buckets of aerated site water overnight to allow them to depurate sediment and gut contents. The next day, fish were removed from the buckets using a small decontaminated dip-net, placed on decontaminated foil and randomly sorted into at least three composite samples per station.

Only fish between 300 and 1500 mm in length were retained for analysis. The range of fish lengths in each composite sample was estimated during sorting (Table 2.3). Each composite contained both male and female fish. Each composite of fish was wrapped in aluminum foil (shiny side down), placed in plastic bags, labeled, and frozen until shipping to the laboratory for analysis of total mercury, lead, Aroclor 1016, 1221, 1232, 1242, 1248, 1254, 1260, and 1268, and lipid and moisture content. One replicate per station was analyzed for methylmercury. At some stations, more than three replicates were collected. The first three replicates were shipped to the laboratory for chemical analysis. The remaining replicates were shipped to EPA Region IV's Environmental Services Division in Athens, GA for archival.

2.2.4 Fiddler Crab Collection

Fiddler crabs were collected from creek banks at all stations between July 29 and August 2, 1997. Sampling locations were adjacent to oyster deployment and fish collection locations along one side of tidal creek banks. Fiddler crabs were collected by hand using trowels to trap fiddler crabs in their burrows from intertidal creek banks. They were then placed into decontaminated plastic buckets. At least 25 mature crabs between 1 and 3 cm long were collected from each station to achieve a target weight of 35 g (wet weight) per sample for analysis. Crabs were rinsed in site water and were

held overnight in the plastic buckets with approximately 5 L of site water and a wire mesh structure (half of a minnow trap) to allow depuration of sediment from the guts of the animals. The next day, crabs from each station were randomly divided into three composite replicate samples. Crabs were wrapped in aluminum foil (shiny side down), placed in plastic zip-lock bags, labeled, and frozen prior to shipment. Samples were shipped to the laboratory by overnight courier for analysis of total mercury, lead, Aroclor 1016, 1221, 1232, 1242, 1248, 1254, 1260, and 1268, and lipid and moisture content. One replicate per station was analyzed for methylmercury.

2.2.5 Resident Oyster Collection

Stations 4 and 5 in the LCP ditch and Station 10 in Purvis Creek were selected for resident oyster collection. Oysters were collected at station 2, but the sample was lost prior to analysis. Resident oysters at Station 10 were much smaller than those found at Stations 4 and 5. The oyster beds at Stations 4 and 5 were much denser, but also contained a high number of empty shells.

Between July 29 and July 31, 1997, resident oysters were collected from within 10 m of the locations selected for deployment of caged oysters. Prior to collecting resident oysters, the size of the specimens was evaluated to determine approximately how many would be required to fulfill the biomass requirements for chemical analysis. All practical efforts were made to collect at least the minimum number of specimens from each location. Only oysters on top of the sediment, not buried under sediment were collected. The resident oysters were collected by hand during low tide from creek banks. A decontaminated pry bar was used to separate the oysters from their substrates if firmly attached. All oysters from a station were held in plastic buckets full of site water for overnight depuration. The next day, oysters from each station were wrapped in aluminum foil, placed in plastic bags, labeled, frozen, and shipped by overnight

courier to the laboratory for analysis of total mercury, lead, Aroclor 1016, 1221, 1232, 1242, 1248, 1254, 1260, and 1268, and lipid and moisture content. One composite from each station was shipped to the laboratory. The chemical analysis lab shucked the oysters and then divided them into composite samples per station for analysis. One replicate per station was analyzed for methylmercury.

2.2.6 Caged Oysters

2.2.6.1 Oyster Collection and Shipment

Oysters (*Crassostrea virginica*) for transplant were provided by Hooper Family Seafood, Smyrna, North Carolina. Seed oysters are obtained from Bear Creek Shellfish, Swansborough, NC, and are raised in Smyrna in a controlled flow-through system. The water used in the flow-through system originates approximately 10 km from Cape Lookout.

The oysters were shipped via overnight courier to the Skidaway Institute of Oceanography in Savannah, GA where they were removed from their packing material and placed into tanks under flow-through conditions with nearby seawater. The oysters appeared to be in excellent health, with less than 0.5 percent mortality due to shipment. They were held at the Skidaway facility for approximately two weeks before deployment at the LCP and reference stations. This two-week holding period allowed the oysters to acclimate to temperature and salinity conditions characteristic of the area.

2.2.6.2 Sorting and Distribution

Whole-animal wet-weight was the criterion used to select oysters to be deployed for this study. Detailed attention was given to the care and handling of the oysters

throughout the process to minimize stress to the animals and to ensure that all test animals were of high quality. Only live oysters that were fully closed, or those that closed immediately upon light physical stimulation were used. Following an initial assessment of the available size range, the oysters were distributed to the mesh tubes on July 28, 1997. The unsorted oysters were held in the flow-through system until needed for distribution. During the distribution process, the oysters were maintained within their acclimated temperature range by placing them in tubs of water; the water was taken directly from the flow-through tanks and changed frequently to maintain oxygen levels and eliminate the potential for the buildup of waste products. Based on the distribution of sizes, and the amount of tissue required for chemical analyses, oysters greater than 15.0 g ww were selected for use in this study.

Just prior to placement in the mesh tube, each individual oyster was measured for its whole-animal wet-weight to the nearest 0.01 g with an electronic balance. The oyster was then placed into a pre-labeled mesh tube (approximately 10 cm in diameter and 2 m long; 2 cm mesh size). Nylon cable ties were used to separate individual oysters within the mesh tube. Each tube contained 10 oysters; five tubes of 10 oysters were prepared for each cage, for a total of 50 oysters per cage. After all oysters were distributed to the mesh tubes, they were returned to the flow-though holding tanks at Skidaway until deployment on August 1, 1997.

2.2.6.3 Deployment

On August 1, 1997, all the oysters were taken from their holding facility at the Skidaway Oceanographic Institute, placed into ice chests, and transported to the staging area between Reference Stations 1 and 2. At this time, the oysters to be deployed at Reference Stations 1 and 2 were removed from the ice chest and affixed to cages approximately 0.5-m wide by 1-meter high constructed of 2.5-cm diameter

polyvinyl chloride (PVC) pipe material. Three cages were prepared for each station. For each cage, the five mesh tubes containing oysters labeled as Bag-1, Bag-2, Bag-3, Bag-4, and Bag-5 for that cage were secured to the PVC frame with large nylon cable ties. The cages were then wrapped with the heavy-duty plastic screen (approximately 2.5-cm mesh size) to discourage predators. The remaining oysters were transported to the LCP facility where they were prepared for deployment at Stations 3 through 10. All cages were deployed on August 1, 1997.

One continuously recording temperature monitoring device was attached to one of the three cages prepared for each station and set to collect temperature data at 12-minute intervals over the deployment period.

During the project design stage, a random numbers table was used to assign cages to stations. The cages, numbered from 1 to 33 were assigned station numbers by using the first two digits of the five-digit random numbers. If the two-digit number was between 01 and 11, it was used as the station number for Cage 1. The next two-digit number between 01 and 11 was identified and used as the station number for Cage 2. This process was continued until all cages were assigned a station number from 1 through 11, with three occurrences of each station number. Oysters designated for station 11 were used for beginning-of-test weight measurements and then sacrificed for chemical analysis of tissues.

An Analysis of Variance (ANOVA) was used to confirm statistically similar sizes among cages and stations ($\alpha = 0.05$). At the beginning of the test, the mean oyster weight was statistically similar among all cages, except for oysters to be used for the beginning-of-test weights and chemical analyses; these oysters had slightly lower mean weights .

The cages containing oysters were deployed at all reference and test stations in a linear fashion. The three oyster cages assigned to a particular station were placed approximately 5 m apart along a transect at the center of each station (Figure 2.3). Cement blocks were used to secure the cages and prevent movement over the tidal cycle. Stakes, surface markers, and flags were used to mark each station. A warning sign to discourage vandalism or removal by trespassers was attached to each station marker. Station position coordinates were obtained using a global positioning system (GPS). Latitude and longitude coordinates for the stations are provided in Table 2.1

2.2.6.4 Beginning-of-test Tissue Preparation

An additional 150 oysters (i.e., three groups of 50 oysters each) were used for initial tissue weight determinations and chemical analyses to obtain background concentrations of contaminants. The average whole-animal wet-weights by replicate for these 150 oysters were slightly less than the average weights for field-deployed oysters even though the size range was the same. Slightly smaller individuals were selected for the initial chemical analyses to ensure sufficient numbers of larger individuals for deployment.

All equipment (i.e., shucking knives and the aluminum foil covering the cutting boards) used during tissue extraction was thoroughly cleaned before processing a new batch (i.e., replicate) according to the following process: wash with Liquinox, rinse with hot tap water, rinse with deionized water. Prior to tissue removal, all staff thoroughly washed their hands with Liquinox. Gloves were worn during the shucking process to reduce the potential for contamination. The shucking process began by separating, or popping, the oyster shells with a special shucking tool. Once separated, a thin-bladed stainless steel knife was used to separate the oyster soft tissues from the shell. The

severed tissue was held in such a position that the excess liquid was allowed to drain. The soft tissues were kept on the shell during extraction and after complete separation. The shell was used as a "holding dish" until tissue weights were made. A weigh pan was made from decontaminated aluminum foil. The soft tissues were placed on the weigh pan using the original shucking knife.

When all tissues of a "replicate" were weighed, the tissues were transferred from the weigh pan to certified clean sample jars provided by the analytical laboratory. The sample jar was tightly capped, affixed with a prepared label, and placed in the freezer. The aluminum foil weigh boat and cutting board cover were discarded after all tissues of a given replicate were shucked and weighed. All shucking equipment was decontaminated before proceeding to the next sample.

2.2.6.5 End-of-Test Measurements and Tissue Preparation

All oyster cages were successfully located and retrieved after the 62-day exposure period. Oysters at Stations 1, 3, 4, 5, 6, and 8 were retrieved on October 1, 1997; oysters at Stations 2, 7, 9 and 10 were retrieved the following day. After removal from the field stations, the caged oysters were transported to Station 2 (the deeper water reference site) for an overnight depuration period. This provided the oysters an opportunity to purge contaminated sediment, if present, from their guts.

The end-of-test measurements involved determining whole-animal wet-weights and soft tissue weights for each live individual. The oysters were processed one cage at a time. Prior to making these measurements, the oysters were assessed for overall condition, and the number of dead and/or missing animals was recorded for each station. Oysters that were gapping or did not close upon light physical stimulation were considered dead. The oysters were removed from the mesh tubes and placed in sequence starting with the

first oyster in Bag 1, into compartmentalized holding trays. If a dead oyster was encountered, the empty shells were placed into the compartmentalized holding tray as a marker. These holding trays were then placed into tubs containing site water from where Purvis Creek joins the Turtle River to eliminate air bubbles between the oyster shells. Starting with the first oyster, each oyster was taken from the holding tray, blotted dry, and the whole-animal wet-weight measurement was made using an electronic balance. The weighed oyster was then put into a second compartmentalized tray to maintain proper sequence. The weight data were recorded manually on laboratory data sheets and electronically to a computer file. The process was repeated until all individuals of a given cage were measured.

For each cage, tissues from all live oysters were removed from the shells as described above and composited for chemical analysis. The sample jar was tightly capped, affixed with a prepared label, and placed in the freezer. The frozen oyster tissue samples were hand carried to Seattle, Washington and then shipped in an ice chest packed with ice to Columbia Analytical Services, Inc., of Kelso, Washington, for homogenization, lipid analysis, percent water determination, and chemical analysis of total mercury, methylmercury, lead, and Aroclor 1016, 1221, 1232, 1242, 1248, 1254, 1260, and 1268.

2.3 Chemical Analyses and Quality Assurance Procedures

All samples were received, stored, prepared, and analyzed according to the quality assurance program of Columbia Analytical Services (CAS), Inc. Analytical results were provided as Tier II data deliverables. Upon receipt, the samples were assigned an internal tracking number. The samples were preserved by freezing and stored until further processing.

For each chemical replicate, all tissues comprising that replicate were homogenized using stainless steel homogenization equipment. All equipment was cleaned with Alconox and thoroughly rinsed with deionized water. All samples were homogenized prior to weighing aliquots for the various analytical parameters.

Method blank analyses were conducted with each analytical test. Surrogate recoveries were conducted for all applicable organic analyses. Additional quality control analyses included analysis of laboratory duplicates, matrix spike, and matrix/duplicate matrix spike samples.

All tissue, sediment, and surface water samples were analyzed for total mercury, lead, and Aroclor 1016, 1221, 1232, 1242, 1248, 1254, 1260, and 1268. A subset of samples was analyzed for methylmercury. Additional analytical parameters included lipids and moisture content for tissues, and grain size, total organic carbon, total sulfides, and moisture content for sediment. Table 2.4 presents a summary of the number of sample types for each analytical parameter for the monitoring program. Surface water samples were analyzed for nutrients such as dissolved organic carbon, nitrogen, iron, and manganese to aid in data interpretation.

One cross contamination blank, consisting of ashless filter paper, was submitted for analysis with each tissue sample. One additional sample of sediment and tissue was submitted to the laboratory for quality assurance purposes. Extra volumes from all water samples were used for QA purposes.

Methylmercury analyses were conducted by Brooks Rand in accordance with Standard Operating Procedure #BR-0011. Prior to analysis, the tissue samples were digested in 25 percent KOH in methanol (w/v) in Teflon vials for four hours at 65^{o}C. Samples

were then analyzed by aqueous phase ethylation, Tenax trap collection, GC separation, isothermal decomposition, and atomic fluorescence detection (CVAFS).

Dry weight determinations were made by weighing out tissues on pre-weighed weigh boats, and placing them in a drying oven (105^{o}C). After 16 to 24 hours, the samples were removed and reweighed. One duplicate dry weight was measured for each batch of samples.

Percent lipid determinations were made by the Bligh and Dyer method. Weighed tissue sample aliquots were placed in a glass tissue grinder with chloroform and methanol and ground for at least 2 minutes. More chloroform was added and the sample ground for 30 seconds. Deionized water was added and the sample was ground again for approximately 30 seconds. In the resulting biphase system, the chloroform layer contains the lipids and the methanol-water layer the other fraction. A purified lipid extract is obtained when the chloroform layer is isolated. Samples were then allowed to dry at 55^{o}C for at least 30 minutes. After drying, total lipids were determined by weight and converted to percent lipids based on the original aliquot weight, according to the following equation:

$$\text{Total lipid} = \frac{(\text{weight of lipid in aliquot})*(\text{volume of chloroform layer})}{\text{Volume of aliquot}}$$

Upon receipt, the chemistry data were subjected to a quality assurance/quality control (QA/QC) review. In addition to checking the data against the project-specific data quality objectives, the data were evaluated for holding times, initial calibrations and continuing calibration verifications, blanks, laboratory control sample or certified reference material, duplicate sample analyses, matrix spike analyses, sample result verification, and overall assessment.

To evaluate precision and accuracy in oyster measurements, the following procedures were used. At the beginning and the end of the deployment period, for every 50 oysters measured for weight, five oysters were remeasured. The remeasuring of oyster weight occurred throughout the measurement process as each group of 100 individuals was processed to ensure that all measurements were within the acceptable limits. A 10 percent (± 5 percent) variance in weight was the acceptable limit. If the results of the remeasurements fell outside of these limits, the previous batch of 100 individuals were remeasured.

The accuracy of the measuring devices was determined according to the standard operating procedures for each measuring device. For the balance, this involves calibrating the instrument with a standard weight (200 g). After every 100 measurements made on the balance, the standard weight was applied to the balance. If the balance was off by more than 1 percent (2 g), the balance was recalibrated and the previous batch of 100 individuals reweighed.

2.4 Data Analysis

2.4.1 Patterns in Contaminant Concentrations

All data were statistically analyzed to test for significant differences in total mercury, Aroclor 1268, and lead when compared to the reference areas. Since only one sample from each station was analyzed for methylmercury, these data are only presented graphically. Prior to hypothesis testing, the data were first evaluated to ensure that they met the assumptions of the statistical tests (i.e., approximate normality and homogeneity of variances). This evaluation was performed using boxplots, normal probability plots, and other graphical diagnostic procedures. For those data that appeared to violate the assumptions of the statistical tests transformations were used,

including logarithms or normalized rank scores (rankits). A parametric ANOVA performed on the rankits is analogous to performing a Kruskal-Wallis test, the non-parametric equivalent of an ANOVA. Differences in either direction were of interest.

Three composited samples were prepared for each station (except for water samples), therefore, the level of replication for the bioaccumulation data is three. The following basic null hypotheses were tested:

- H_0: There are no significant differences in the amount (concentrations or content) of mercury, lead, or Aroclor 1268 in tissues or sediment between site stations and reference stations ($\alpha = 0.05$).

- H_0': There are no significant differences in the amount (concentrations or content) of mercury, lead, or Aroclor 1268 in tissues or sediment among site stations ($\alpha = 0.05$).

The replicate chemistry samples (which included both concentration and content data in oysters for each contaminant of concern), were analyzed using a one-way Analysis of Variance (ANOVA) followed by Bonferroni multiple contrasts of the average of the two references to site station means. The Bonferroni multiple contrast was chosen because of its ability to account for the number of means being tested against the references. The experiment-wise error rate was set at 0.05. Differences between the amount of contaminants in oyster tissues at the beginning and end of the study were tested for using Dunnett's test for a control against station means. A Newman-Keuls test was used to test for any significant differences among site stations. Differences in either direction (either greater or less than reference sites) were of interest.

A primary concern underpinning this study design was to evaluate potential sources and pathways for contamination to reach biota. Factors potentially controlling mercury methylation are also of interest. With these concerns in mind, graphical methods were

used to evaluate relationships between contaminant concentrations and distance from the head of the LCP ditch (the location of the former plant outfall) by water (since the site is tidal and contaminated water and suspended sediment could flow upstream during incoming tides- Table 2.8). The head of the LCP ditch was the location of the outfall from the former plant. If the head of the ditch is the source of contamination throughout the site, we would expect to see concentrations decrease with distance from the head of the ditch.

2.4.2 Oyster Survival and Growth

The survival and growth data (i.e., survival, whole-animal wet-weight, and tissue weight data) from the oyster transplant study were also statistically analyzed. Descriptive statistics such as mean and standard deviation were calculated for these parameters. For whole-animal wet-weight and end-of-test tissue weight, each individual oyster was considered a replicate. Therefore, for these measurements the level of replication at each station is 150 (if all oysters survived).

A one-way analysis of variance (ANOVA) followed by Bonferroni's multiple contrast test were used to test the following general null hypotheses:

- There is no significant difference in oyster whole-animal wet-weights between site stations and reference stations ($\alpha = 0.05$).

- There is no significant difference in oyster soft tissue weights between site stations and reference stations ($\alpha = 0.05$).

A one-way ANOVA partitions the variability into two components: the variability within and the variability between stations. If the ratio of these two variances (the between-group variance over the within-group variance) is large enough, observed

differences between means are likely due to true differences between the groups and not just random variation.

If the primary factor of the ANOVA is rejected indicating that differences among all stations were detected, pairwise contrasts were performed using Bonferroni's multiple contrasts test to determine which stations differed from the coupled reference stations. Dunnett's multiple comparisons test was employed to determine differences between end-of-test results and initial conditions. Because two reference stations were used in this study, the hypothesis comparing each site station to "reference" is represented by the following equation:

$$\mu_{site1} = 1/2(\mu_{ref1} + \mu_{ref2})$$

This type of equation was constructed and tested for each of five Purvis Creek stations and three LCP Ditch stations. An experiment-wide 95 percent confidence level ($\alpha = 0.05$) was used for these analyses.

Survival rates for the *in situ* study were based on the number of live oysters found at the end of the test relative to the total number of individuals (both dead and alive) found at the end of the test. Oyster tissues were considered "missing" if there was an empty space between two nylon cable ties. Survival rates among stations were compared using a chi-squared contingency analysis ($\alpha = 0.05$). A chi-square test compares the observed and expected frequencies of animals alive or dead at the end of the test, with the null hypothesis stating that the probability of survival is the same at all stations. If rejected, the contingency table was partitioned to compare each station with a mean survival less than the mean of the reference stations to expected values to determine where differences occurred. 'Expected' frequencies were based on the mean of the percent survival for Reference stations 1 and 2 combined.

2.4.3 Data Correlations

Relationships between the amount of lead, total mercury, and Aroclor 1268 in oyster tissues and the concentrations of these contaminants in water and sediment samples were analyzed using Spearman's non-parametric correlation tests. A non-parametric test was chosen for these analyses because of high variability in some of the data sets and low sample numbers for some of the parameters being tested (for example, only one water sample was taken at each station).

All replicates of tissue chemistry results were compared to replicate samples of bank and creek sediments. However, the tissue chemistry results had to be averaged for each station to compare to single-sample water chemistry data. Because the sample size is so small for these comparisons, the correlation is not very powerful and it is much less likely that correlations between the data will be detected.

Resident oysters were statistically compared to bank and creek sediments and caged oysters using the Spearman correlation for the stations where resident oysters were collected. These results also lack statistical power because of the small sample size taken of the resident animals. No statistical comparisons could be made between resident oysters and water because of limited sample sizes.

Correlations were run to get a sense for relationships between contaminant concentrations in water, sediment, and animals at the LCP site. However, given the limited statistical power, these statistical results should only be used as a rough guideline. The power of the statistical test to detect or reject differences greatly decreases with smaller sample sizes and with multiple usage of the test.

2.4.4 Temperature

Temperature data were downloaded from the logging devices using the instruments' data recovery software. Minimum, maximum, and mean temperatures were calculated for each station. Temperature profiles were generated for each station and used to identify overall temperature trends.

There were two primary hypotheses to be tested:

- Average daily temperatures are not different between sites and reference stations, and
- Weekly ranges of temperatures are not different between sites and reference stations

Prior to testing these hypotheses, temperature profiles were made for each station using the entire set of data collected during the deployment period.

2.4.4.1 Testing for Differences in Mean Daily Temperature

The data files were modified so that the start and end times of the temperature series were similar for all stations; this ensured that the temperature series were of equal length and covered the same time period. These modifications involved dropping some of the temperature data at the very beginning and very end of the data files. Each temperature series displayed trend and cyclical autocorrelation, requiring a non-standard analysis of mean differences.

In order to reduce variability and autocorrelation, each temperature series was reduced to daily mean temperatures using all the data. A pairwise station analysis was then performed on the differences between the daily means at each site. The daily average temperatures were also autocorrelated. To derive an independent data set, the mean differences were

then regularly subsampled at a frequency determined by the autocorrelation function. Because the extent of the autocorrelation in the mean difference series varied from comparison to comparison, the maximum significant autocorrelation measured was used to subsample all sites to provided data sets that were equal in sample sizes. These reduced data sets were tested for differences from zero using one-sample t-tests, with two-tailed alpha-levels of 0.05.

2.4.4.2 Testing for Differences in Temperature Range

Differences in the weekly range of temperatures across stations were also examined. First, the minimum weekly temperature was subtracted from the maximum weekly temperature at each station, resulting in 9 observations of temperature range per station. These series were not significantly autocorrelated, and the variances were approximately equal across stations. Normality was assessed by plotting a histogram and quantile plot for residuals from an initial ANOVA fit. The data were approximately normal, so a one-way ANOVA was performed to test for differences between the weekly ranges.

Table 2.1. Station Locations.

Station	Latitude	Longitude
1 (Crescent, GA, similar to sta 3, 4, 6, 7, 8)	31 ° 31'8.9"	81 ° 21'23.2"
2 (Crescent, GA, similar to sta 5, 9, 10)	31 ° 30'59.3"	81 ° 21'24.5"
3 (tributary to LCP ditch)	31 ° 11'10.72"	81 ° 30'48.66"
4 (in the LCP ditch)	31 ° 11'12.81"	81 ° 30'46.31"
5 (at the confluence of the LCP ditch at Purvis Creek)	31 ° 11'15.03"	81 ° 30'55.59"
6 (in a tributary to Purvis Creek)	31 ° 11'4.42"	81 ° 30'56.55"
7 (in a tributary to Purvis Creek)	31 ° 11'6.86"	81 ° 31'00.30"
8 (in a tributary to Purvis Creek)	31 ° 11'7.73"	81 ° 31'1.81"
9 (in Purvis Creek)	31 ° 11'8.67"	81 ° 30'59.39"
10 (near the confluence of Purvis Creek and the Turtle River)	31 ° 10'55.42"	81 ° 31'14.31"

Table 2.2 Numbers of samples collected at each of the LCP monitoring stations

Station	Creek Sediment	Surface water[a]	Deployed oysters	Resident oysters	Fish	Crabs	Bank Sediment
1 (Reference)	9	2	3		5	3	9
2 (Reference)	9	2	3		3	3	9
3	9	2	3		6	3	9
4	9	2	3	3	9	3	9
5	9	2	3	2	3	3	9
6	9	2	3		9	3	9
7	9	2	3		9	4	9
8	9	2	3		9	3	9
9	9	2	3		1	3	9
10	9	2	3	1	3	3	9
Total	90	20	30	6	59	31	90

a: Surface water samples were collected at both high and low tide at all sampling stations.

Table 2.3 Sample parameters *Fundulus heteroclitus*

Station/ composite	Number of Fish	Approximate Size range	Packaging Date
1-1	10	4-9 cm	8/1/97
1-2	7	5-15 cm	8/1/97
1-3	10	3-10 cm	8/1/97
2-1	16	3-6 cm	8/3/97
2-2	16	3-6 cm	8/3/97
2-3	16	3-6 cm	8/3/97
3-1	6	5-15 cm	8/1/97
3-2	5	5-15 cm	8/1/97
3-3	8	3-12 cm	8/3/97
4-1	9	5-10 cm	7/31/97
4-2	7	7-10 cm	7/31/97
4-3	7	5-10 cm	7/31/97
5-1	8	3-5 cm	8/3/97
5-2	13	3-10 cm	8/3/97
5-3	10	3-10 cm	8/3/97
6-1	43	5-8 cm	7/31/97
6-2	40	5-8 cm	7/31/97
6-3	44	5-8 cm	7/31/97
7-1	17	4-7 cm	7/31/97
7-2	16	4-7 cm	7/31/97
7-3	18	4-7 cm	7/31/97
8-1	17	3-9 cm	7/31/97
8-2	17	3-9 cm	7/31/97
8-3	17	3-9 cm	7/31/97
9-1	16	3-7 cm	8/26/97
10-1	15	3-7 cm	8/26/97
10-2	15	3-7 cm	8/26/97
10-3	16	3-7 cm	8/26/97

Table 2.4 Numbers and types of samples analyzed for each parameter[a].

Analyte	Sediment	Surface Water		Fish Tissue	Oyster Tissue	Crab Tissue
		Total	Dissolved			
Lead	60	20	20	28	36	25
Total Mercury	60	20	20	28	37	31
Methylmercury	20[b]	3[c]	3[c]	10[b]	14[b]	10[b]
PCBs	60	20		28	36	22
Percent Moisture	60			28	37	31
Total Organic Carbon	60					
Total Sulfides	60					
Grain Size	60					
Nutrients		20	20			
Suspended Solids		20				
Percent lipids				28	36	22

a: Numbers do not include field replicates taken for QA purposes.

b: One replicate per station was analyzed for methylmercury.
One T_0 oyster sample was analyzed for methylmercury.

c: Methylmercury was analyzed in water samples taken at low tide only at only 3 stations.

Table 2.5 Chemical analysis methods and detection limits for water samples.

Analytes	Laboratory	Method Reporting Limits (units)	EPA Method Number or Reference
Total Hg	CAS	5 ng/L	1631 M
Pb	CAS	2 µg/L	7421
PCBs	CAS	0.2 µg/L	3510B/8080A
MeHg	Brooks Rand, Ltd.	0.025 ng/L	BR-0011 (CVAFS)
Iron	CAS	20 µg/L	6010A
Manganese	CAS	5 µg/L	6010A
Ammonia Nitrogen	CAS	50 µg/L	350.1
Nitrate Nitrogen	CAS	200 µg/L	300.0
Nitrite Nitrogen	CAS	200 µg/L	300.0
Total Suspended Solids	CAS	5 mg/L	160.2
Dissolved Organic Carbon	CAS	500 µg/L	415.1

Table 2.6 Chemical analysis methods and detection limits for sediment samples

Analytes	Laboratory	Method Reporting Limits (units)	EPA Method Number or Reference
Total Hg	CAS	10 µg/Kg dry	7471A
Pb	CAS	2 mg/Kg dry	7420
PCBs	CAS	28 µg/Kg dry	3540B/8080A
MeHg	Brooks Rand, Ltd.	0.002 µg/Kg wet	
Grain Size	CAS		ASTM D422 Modified
Total Sulfide	CAS	1 mg/Kg dry	9030M
Total Organic Carbon	CAS	0.05% dry	ASTM D4129-82M

Table 2.7 Chemical analysis methods and detection limits for tissue samples

Analytes	Laboratory	Method Reporting Limits (units)	EPA Method Number or Reference
Total Hg	CAS	10 µg/Kg dry	7471A
Pb	CAS	20 µg/Kg dry	200.8
PCBs	CAS	19 µg/Kg wet	3540B/8080A
MeHg	Brooks Rand, Ltd.	1 µg/Kg wet	BR-0011 (CVAFS)

Table 2.8 Estimated Distance from the Head of the LCP ditch (by water)

Station Number	Estimated Distance (m)
3	462
4	246
5	477
6	885
7	939
8	962
9	700
10	1577

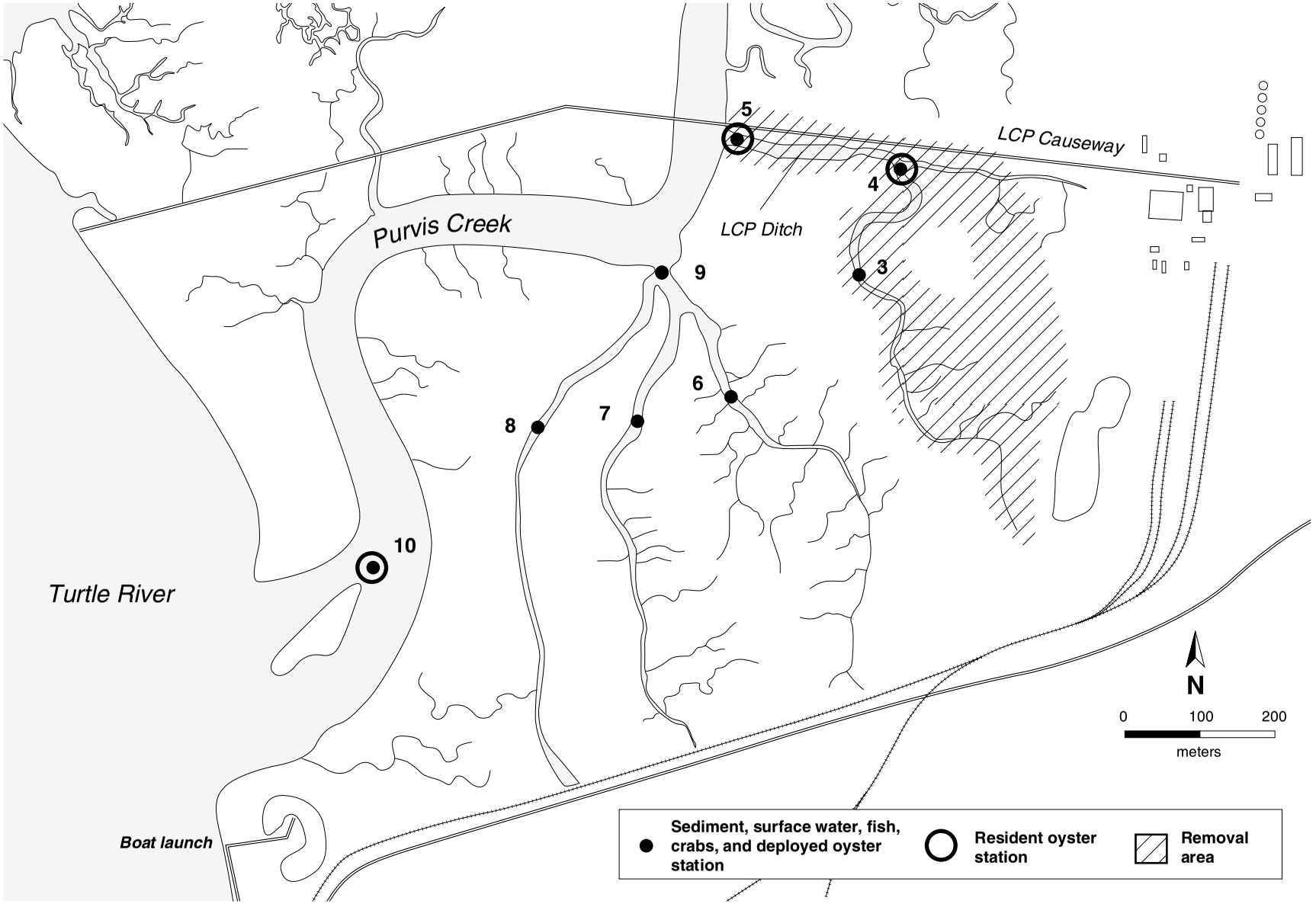


Figure 2.1. Sampling locations

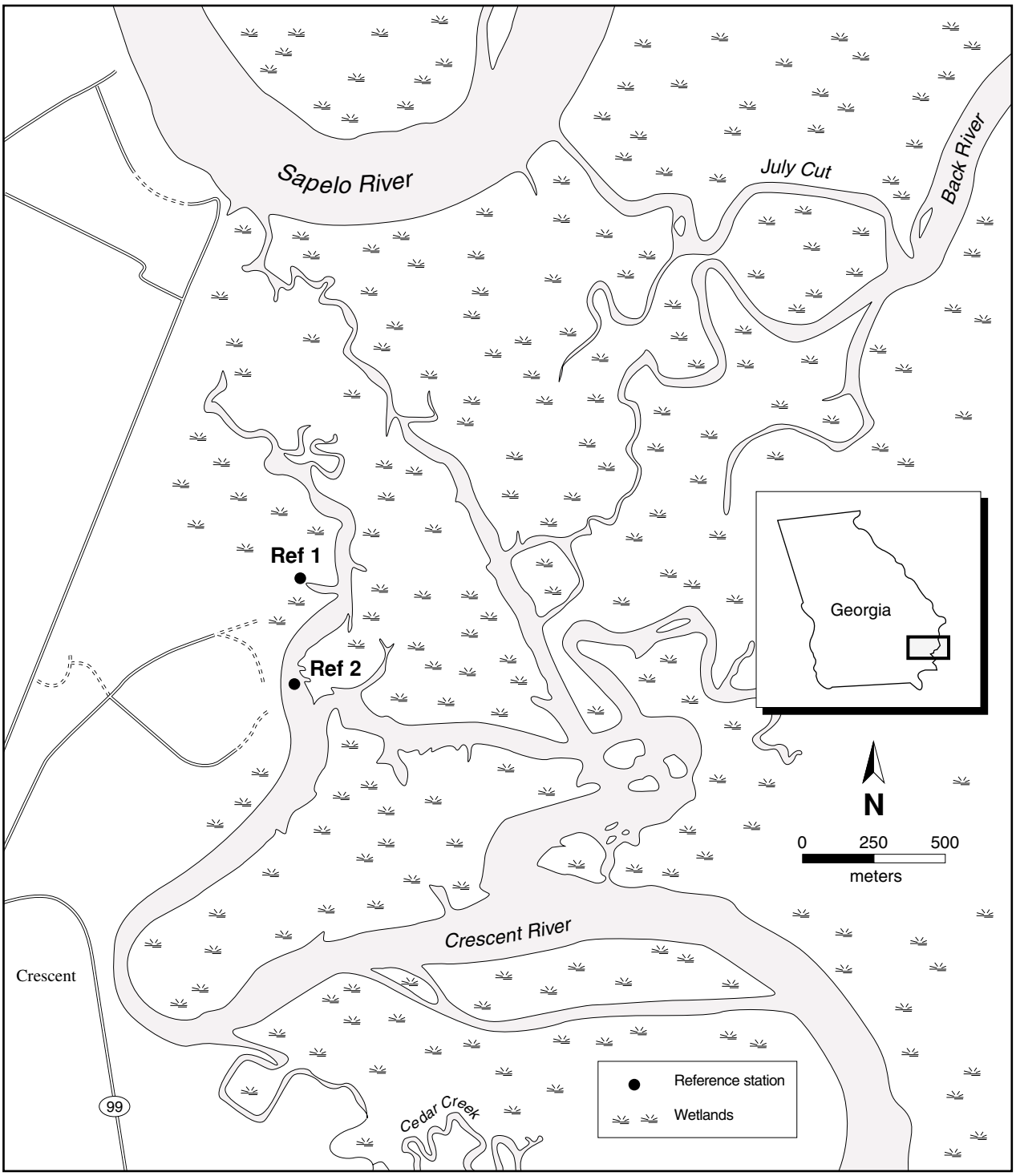


Figure 2.2. Reference stations on the Crescent River

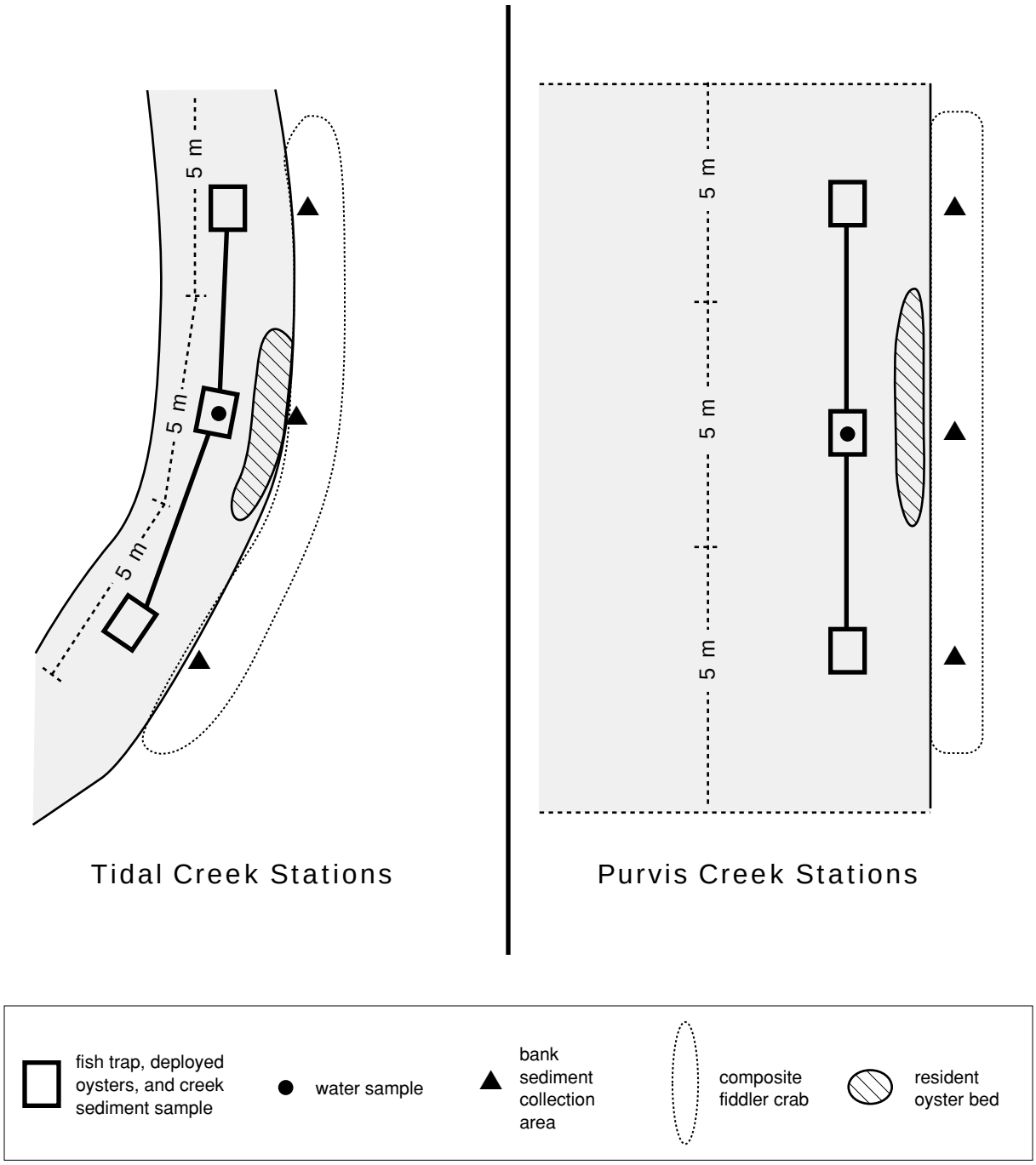


Figure 2.3. Sampling scheme for fish, crabs, sediments, water, deployed and resident oysters

3.0 Results

Statistical comparisons and results of correlation analyses are presented in Appendix A.

3.1 Data Quality

All data were considered usable for the purposes of this report. Data qualified *J* are considered usable as estimates. A summary of the data review is provided in this section. Chemicals reported as undetected were included in statistical calculations using a value of one-half of the reported detection limit.

Metals (lead and total mercury) - A method blank was digested and analyzed with each batch of samples. There were no target analytes present. A matrix spike was analyzed with each batch and all results were within the laboratory specified control limits of 60-130 percent. A sample duplicate was analyzed with each batch and the results met the RPD limit of ±35 percent, with the exception of one crab sample, which was qualified as an estimate.

Methylmercury - A method blank was digested and analyzed with each batch of samples. Methylmercury was detected in method blanks for some of the sediment analyses and some of the fish analyses. As part of the laboratory's standard operating procedures, blank correction was performed and all sample results are usable as reported. A matrix spike was analyzed and the percent recoveries were within the specified limits of 60-130 percent. In addition, a certified reference material was analyzed with each batch and the results were within the specified control limits of 75-125 percent. A sample duplicate was analyzed with each batch and the results met the RPD limit of ±35 percent.

Polychlorinated biphenyls - A method blank was extracted and analyzed for samples submitted for PCB analyses and there were no target compounds present. All surrogate recoveries were within the laboratory established quality control limits of 20-140 percent, with the exception of some sediment and crab samples which are qualified as estimates. Matrix spike and matrix spike duplicate samples (utilizing Aroclor 1268) were analyzed and all percent recoveries were within the established quality control limits of 46-148 percent. In addition, the RPDs derived from the matrix spike and matrix spike duplicate analyses were within the limit of ±35 percent. A blank spike sample was analyzed with the oyster tissue and the percent recoveries were within the specified quality control limits of 46-148 percent.

Other measurements- Analysis of sulfides in sediments for 12 samples were conducted past recommended holding times. All oyster growth and bioaccumulation data are considered usable for the purpose of this report. The remeasurement process indicated that field staff were consistent in the measurement technique and that the error associated with those measurements was well within the 5 percent allowable deviation.

3.2. Water

Statistical comparisons were not performed since only one replicate was taken at each station. Water data is presented in Table 3.1 and Figure 3.1. Due to interference by chloride ions, nitrate and nitrite nitrogen were not detected in any samples at detection limits of 100 mg/L (nitrite) and 5 mg/L (nitrate).

3.2.1 Mercury

Highest concentrations were detected in low tide unfiltered water samples. Highest concentrations (341 and 398 ng/L) were detected at stations 3 and 4, lowest concentrations

at stations 9 and 10 (43 and 46 ng/L). Moderate concentrations were found at stations 5, 6, 7, and 8. Chronic ambient water quality criteria for freshwater (12 ng/L) and marine water (25 ng/L) were exceeded at all stations at low tide. Total mercury was not detected in low tide water samples at the reference stations (<5 ng/L). A similar pattern was observed in dissolved mercury concentrations at low tide, with highest concentrations at stations 3, 4, and 5, and lowest concentrations at stations 9 and 10.

There appears to be a pattern between total mercury in low tide unfiltered water and distance from the head of the LCP ditch, with stations 6, 7, and 8 being somewhat elevated over what would be expected if the head of the ditch were the only source of mercury in water at low tide (Figure 3.2).

At high tide, the pattern is less distinct (Figure 3.3). The highest concentration of total mercury was detected at station 4 (136 ng/L), and the lowest concentration found at station 10 (26 ng/L), where concentrations were similar to those at the reference stations (23-26 ng/L). Dissolved mercury in high tide samples was highest at station 9 (30 ng/L). Chronic AWQC values were exceeded by all unfiltered samples at high tide, but only at station 9 in filtered samples.

The three low tide samples analyzed for methylmercury indicate that methylmercury at station 5 is higher than that at stations 9 and 10. Between 5 and 12% of particulate mercury (the proportion of total mercury in unfiltered water) is methylated. Unfiltered water samples contained 14.4 ng/L of methylmercury at station 5, while unfiltered water samples contained 2.4 ng/L. Approximately 5% of dissolved mercury is in the methylated form.

The concentration of total suspended solids in unfiltered water at low tide is not sufficient to explain differences between stations in total mercury concentrations, although unfiltered

water concentrations are always higher than filtered water concentrations. At high tide, suspended solid concentrations are fairly uniform across the site, while total mercury concentrations are highest at station 4. At low tide, total suspended solid concentrations are much higher at station 5 (1350 mg/L) than at other stations (where concentrations are below 100 mg/L), but total mercury concentrations are still highest at station 4.

3.2.2 Aroclor 1268

Filtered water samples were not analyzed for PCBs. Aroclor 1268 was only detected in low tide unfiltered water samples and was not detected at high tide (with a detection limit of 0.2 µg/L). Stations 3, 4, 5, and 7 had detectable Aroclor 1268 concentrations, with the highest concentration at station 5 (5.5 µg/L) and the lowest concentration at station 7 (0.3 µg/L). Aroclor 1268 was not detected in water samples from the reference sites. Other Aroclors were not detected in any samples with detection limits of 0.2 µg/L. The detection limits exceed both the chronic ambient water quality criteria for freshwater (0.014 µg/L) and for marine water (0.03 µg/L).

3.2.3 Lead

Lead was detected only in unfiltered water samples at only three stations (with a detection limit of 2 µg/L). Reference station 2 contained 11 g/L in the high tide sample, but lead was not detectable at low tide. At stations 5 and 7 lead was detected at low tide (20 µg/L and 5µg/L, respectively). The chronic ambient water quality criteria for lead is 3.2 µg/L for freshwater and 8.5 µg/L for marine water.

3.3 Sediment

Results of sediment analysis are presented in Figures 3.4-3.6 and Tables 3.3 and 3.4. Methylmercury was detected in some of the method blanks for sediment analyses (at a concentration of 0.003 µg/Kg wet weight). Data was blank corrected by the laboratory,

which adjusts dry weight concentrations by 0.004 to 0.045 µg/Kg. Comparisons between concentrations of contaminants in sediment and other sediment parameters, and between contaminants in bank and creek sediment are provided in Appendix A.2.

3.3.1 Mercury

Bank sediment total mercury concentrations were log transformed before statistical comparison. All stations at the site were statistically elevated in total mercury concentration when compared to the two reference sites ($p<0.05$).

The two reference stations are not different from each other in bank total mercury concentration. Stations 3, 4, 5 are similar in concentration to each other, but significantly higher than all other stations sampled (Appendix A).

There appears to be a general relationship between total mercury in bank sediment total mercury concentrations nearest the site and distance from the head of the LCP ditch, with station 3 being somewhat elevated over what would be expected if the head of the ditch were the only source of mercury to bank sediment (Figure 3.7). Stations farther away from the ditch head (Stations 9, 6, 7, 8, and 10) appear to be uniformly contaminated with lower levels of total mercury. The pattern is similar in grain-size normalized and non-normalized data. The same pattern is seen in methylmercury concentrations in bank sediment. Bank sediment contains low percentages of methylmercury: from 0.07% at station 5 to 1.5% at station 9.

Creek bottom sediment total mercury concentrations were rank-it transformed before statistical comparison. All stations at the site were statistically elevated in total mercury concentration when compared to reference sites ($p<0.05$). The two reference stations are

not different from each other in bank total mercury concentration. Station 4 is more highly contaminated than all other stations sampled (Appendix A).

There is a good relationship between total mercury in creek sediment total mercury concentrations and distance from the head of the LCP ditch (Figure 3.8). The pattern was similar in grain size normalized and non-normalized results. The pattern is similar for methylmercury concentrations in creek sediment. Creek sediment contains low percentages of methylmercury: from 0.006% at station 5 to 0.5% at station 9.

3.3.2 Aroclor 1268

Bank sediment Aroclor 1268 concentrations were log transformed before statistical comparison. All stations at the site were statistically elevated in Aroclor 1268 concentration when compared to the two reference stations ($p<0.05$).

The two reference stations are not different from each other in Aroclor 1268 concentration. Stations 3, 4, 5 are similar in concentration to each other, but higher than all other stations sampled. Stations 7, 8, 9, and 10 are similar to each other in concentration. Station 6 is different from all other stations (Appendix A).

Stations closest to the site have highest PCB concentrations, but except for stations 3, 4, and 5 concentrations are uniform (Figure 3.9). Differences between sites are minimized when concentrations are normalized to grain size and TOC, but Station 5 has higher Aroclor 1268 concentrations in bank sediment than what would be expected if the head of the ditch were the only source of Aroclor 1268 to bank sediments.

Other Aroclors were not detected in any samples of creek or bank sediment with detection limits that vary between 0.028 mg/Kg and 2.8 mg/Kg (due to the requirements to dilute highly contaminated sample extracts to quantify Aroclor 1268).

Creek bottom sediment Aroclor 1268 concentrations were rank-it transformed before statistical comparison. All stations at the site were statistically elevated in Aroclor 1268 content when compared to the two reference stations ($p<0.05$).

The two reference stations are not different from each other in Aroclor 1268 concentration.

Stations closest to the site have highest PCB concentrations, but except for stations 3, 4, and 5 concentrations are fairly uniform (Figure 3.10). The pattern is similar in normalized and non-normalized sediment (Appendix A).

3.3.3 Lead

Bank sediment lead concentrations were log transformed before statistical comparison. All stations at the site were statistically elevated in lead content when compared to the two reference stations ($p<0.05$). The two reference stations are not different from each other in lead concentration. Stations 4 and 5 are different from each other and more highly contaminated than all other stations (Appendix A).

Non-normalized bank sediment generally declines in lead concentration away from the head of the ditch, except that lead at station 5 is elevated above what would be expected if the head of the ditch were the source of all contamination (Figure 3.11).

Creek bottom sediment samples were statistically significantly higher in lead concentration than bank samples at station 4 ($p=0.046$). At station 1, bank sediment contained higher concentrations of lead than creek bottom sediment ($p=0.034$). At all other stations, there was no difference between bank and creek bottom sediment lead concentrations ($p>0.05$).

Creek bottom sediment lead concentrations were log transformed before statistical comparison. All stations at the site were statistically elevated in lead content when compared to the two reference stations ($p<0.05$). The two reference stations are different from each other in lead concentration, with station 2 having higher lead concentrations in creek bottom sediment ($p=0.0015$). Stations 4 and 5 are similar to each other in lead concentration, but higher than all other stations (Appendix A).

Creek sediment generally declines in lead concentration away from the head of the ditch, except that lead at station 5 is higher than what would be expected if the head of the ditch were the source of all contamination. Grain size normalized and non-normalized data have a similar pattern.

3.4 Fish

Results of fish sampling are presented in Figures 3.13-3.16 and Table 3.4. Methylmercury was detected in some of the method blanks for fish analyses (at a concentration of 0.004 µg/g dry weight). Data was blank corrected by the laboratory. Correlations between parameters are presented in Appendix A.2.

3.4.1 Mercury

Fish mercury concentrations were not transformed before statistical comparisons. All stations at the site were statistically elevated in total mercury concentration when compared to the two reference stations ($p<0.05$).

Fish at the two reference stations are not different from each other in total mercury concentration. Stations 3 and 4 are similar in concentration to each other, but higher than all other stations sampled. Station 5 is different from all other stations (Appendix A).

Concentrations of total mercury in fish decline steadily away from the head of the LCP ditch (Figure 3.17). Methylmercury in fish follows the same pattern as total mercury. The percentage of methylmercury in fish ranges from 66.5% at one of the reference stations (station 1) to 90-100% at site stations.

3.4.2 Aroclor 1268

Fish Aroclor 1268 concentrations were rank-it transformed before statistical comparison. All stations at the site were statistically elevated in Aroclor 1268 concentration when compared to the two reference stations ($p<0.05$). Other Aroclors were not detected in any fish samples with detection limits that vary between 0.08 µg/g and 1 µg/g dry weight (due to the requirements to dilute highly contaminated sample extracts to quantify Aroclor 1268).

The two reference stations are not different from each other in Aroclor 1268 concentration. The fish concentration at station 4 is higher than all other stations sampled. Stations 3 and 5 are similar in concentration to each other, but different from all other stations sampled (Appendix A).

Stations closest to the site have highest fish PCB concentrations, but except for stations 3, 4, and 5, concentrations are fairly uniform (Figure 3.18). Normalizing concentrations to lipid content results in a uniform pattern, with the exception of fish at station 4.

3.4.3 Lead

Fish lead concentrations were rank-it transformed before statistical comparison. All stations at the site were statistically similar in lead concentration when compared to the two reference stations except for station 10, which had a significantly lower lead concentration than the mean of the reference sites ($p<0.05$).

The two reference stations are not different from each other in lead concentration. Station 8 has significantly higher lead concentrations in fish than stations 9 and 10 (Appendix A).

There is no obvious pattern in lead concentrations in fish with distance from the head of the ditch (Figure 3.19).

3.5 Fiddler crab

Results of analysis of fiddler crabs is presented in Figures 3.20-3.23 and Table 3.5. Correlations between parameters are presented in Appendix A.2.

3.5.1 Mercury

Fiddler crab mercury concentrations were log transformed before statistical comparisons. All stations at the site were statistically elevated in total mercury concentration when compared to the two reference stations ($p<0.05$-Appendix A). Fiddler crabs at the two reference stations are not different from each other in total mercury concentration.

Total mercury in crab declines with distance from the head of the LCP ditch (Figure 3.24). Concentrations of total mercury in crab are slightly elevated at stations 6, 7, and 8 compared to what might be expected in the head of the ditch were the only source of mercury to crabs. The pattern of methylmercury in crabs is similar, but with lower concentrations at station 4 than might be expected based on total mercury concentrations (Figure 3.25). The percentage of methylmercury in crabs ranges from 38.2% at station 4 to 100% at reference station 1.

3.5.2 Aroclor 1268

Fiddler crab Aroclor 1268 concentrations were not transformed before statistical comparison. Fiddler crabs from stations 3, 4, and 9 were not analyzed for Aroclor 1268 due to limited tissue volume. Other Aroclors were not detected in any crab samples with

detection limits that vary between 0.08 µg/g and 0.5 µg/g dw (due to the requirements to dilute highly contaminated sample extracts to quantify Aroclor 1268), except at station 1, where one replicate of crabs contained 0.520 µg/g dw Aroclor 1254. All stations at the site were statistically elevated in Aroclor 1268 concentration when compared to the two reference stations ($p<0.05$), except for station 6.

The two reference stations are not different from each other in Aroclor 1268 concentration. The concentration at station 5 was higher than all other stations sampled (Appendix A).

3.5.3 Lead

Fiddler crab lead concentrations were not transformed before statistical comparison. Fiddler crabs from stations 3 and 4 were not analyzed for lead due to limited tissue volume available. All stations at the site were statistically different in lead concentration when compared to the two reference stations except for station 10 ($p<0.05$).

The two reference stations are not different from each other in lead concentration. Station 10 has lower fiddler crab lead concentrations than all other site stations (Appendix A).

No strong relationship between lead concentrations in crabs and distance from the head of the ditch is apparent, except that concentrations at station 10 are the lowest among those at the site.

3.6 Resident Oysters

Results of sampling for resident oysters are presented in Figures 3.26-3.29 and Table 3.6. Correlations between parameters are presented in Appendix A.2.

3.6.1 Mercury

Statistical comparisons of resident oyster data were not possible due to limited replication (only one sample was analyzed at station 10). Based on the three stations analyzed, no pattern is apparent over the site in total mercury concentrations. Methylmercury concentrations in resident oysters may be lower at station 10 (1.67 µg/g dw) than at stations 4 and 5 (1.75-1.76 µg/g dw). The percentage of methylmercury in resident oyster tissues ranged from 62.6% at station 4 to 70.59% at station 10.

3.6.2 Aroclor 1268

Aroclor 1268 concentrations in resident oysters may be lower at station 5 (0.2 µg/g dw) than at stations 4 and 10 (0.4 µg/g dw). A similar pattern is seen in lipid normalized concentrations. However, Aroclor 1268 was only detected above 0.18 µg/g in four of the six samples, where concentrations ranged from 0.34-0.64 µg/g dw.

3.6.3 Lead

Lead in resident oysters ranged from a mean of 0.53 µg/g dry weight at station 5 to 1.16 µg/g at station 10.

3.7 Transplanted Oysters

Oysters were retrieved from all field stations on October 1 and 2, 1997. Length of deployment was 62 days. Upon retrieval, all cages were in excellent condition. There were no signs of predation or vandalism. In general, the oysters were in very good condition, except for oysters in one cage from Station 4 and one cage from Station 5. All oysters in both of these cages were dead. Ancillary data on caged oysters is presented in Appendix B.

Concentrations in caged oysters may not accurately reflect bioavailability of contaminants if oysters are not actively growing, or if growth rates vary across the site. Therefore, both concentration and content (the mass of contaminant in the animal) are presented and analyzed in this section. Results of chemical analysis of caged oysters are presented in Figures 3.26-3.29 and in Tables 3.6 and 3.7. Correlations between parameters are presented in Appendix A.2.

3.7.1 Mercury

Total mercury concentration at the start of the test by station was estimated at 0.16 µg/g dw. This estimate was based on the total mercury concentration measured for the 150 animals used for time zero, test initiation (T_0) tissue chemistry analyses. Mean total mercury concentrations by station ranged from 0.1 to 3.86 µg/g-dry at the end of the test. The highest concentrations were measured in oysters deployed at Station 3. The concentration of total mercury was lower in oysters deployed at both reference stations after the 62-day deployment period than at the start. Oysters at all other stations accumulated mercury during the deployment period.

The mercury data were suitable for parametric analyses without transformation. The results of the ANOVA indicated significant differences between stations ($p = 0.0002$); the Bonferroni test indicated that total mercury was significantly higher at all sites stations except 9 and 10 when compared to the two reference stations. The site stations were compared to each other with the Newman-Keuls test (Appendix A).

Total mercury content per individual at the start of the test was 0.06 µg. The total mercury content increased in oysters at all stations except those at the reference stations during the 62-day deployment period. The lowest total mercury content was found in oysters at the reference stations; the highest content was found in oysters at Station 3.

The total mercury content data were suitable for parametric analyses with log transformation. The results of the ANOVA indicated significant differences between stations ($p = 0.000001$). The Bonferroni multiple contrast analysis indicated that the total mercury content at all site stations were significantly higher than at the reference stations. In addition to differences between reference stations and stations near the LCP facility, significant differences were found among the LCP stations themselves (Appendix A).

Total mercury concentrations and content in caged oysters generally decline with distance from the head of the LCP ditch, except that stations 6, 7, and 8 have higher total mercury concentrations and content than would be expected if the head of the ditch were the source of all mercury to caged oysters (Figure 3.30).

Methylmercury concentration at the start of the test by station was estimated at 0.18 µg/g dw. This estimate was based on the methylmercury concentration measured for the 150 animals used for time zero, test initiation (T_0) tissue chemistry analyses. Methylmercury concentrations by station ranged from 0.07 to 2.86 µg/g dw. The lowest methylmercury concentrations were measured in oysters deployed at the reference stations; the highest concentrations were measured in oysters deployed at Station 3. The concentration of methylmercury was lower in oysters deployed at both reference stations after the 62-day deployment period than at the start. Oysters at all other stations accumulated methylmercury during the deployment period. No statistical analyses could be done on the methylmercury data due to lack of replication. The proportion of mercury in the methylated form in terms of concentration ranged from 38.8% at station 8 to 100% at stations 2 and 9.

Methylmercury content per individual at the start of the test was 0.07 µg. The methylmercury content increased in oysters at all stations except those at the reference

stations during the 62-day deployment period. The lowest methylmercury content was found in oysters at the reference stations; the highest content was found in oysters at Station 3. No statistical analysis could be done on the methylmercury content data due to the lack of replication. The proportion of mercury in the methylated form in terms of content ranged from 42.61% at station 6 to 100% at station 9. Methylmercury content generally declines with distance from the head of the LCP ditch, except that the methylmercury content at station 3 is higher than would be expected if the ditch were the source of all methylmercury to oysters (Figure 3.31).

3.7.2 Aroclor 1268

Aroclor 1268 was not detected in tissues analyzed at the start of the test at a method detection limit of 0.18 µg/g dw. 150 animals in three replicates of 50 each were analyzed to provide an estimate of concentrations at the start of the test. Other Aroclors were not detected in any caged oyster, except in initally deployed oysters, which contained 0.5 µg/g dw Aroclor 1254. For purposes of graphical and statistical analyses, a value of one-half the method detection limit, 0.05 µg/g, was used for non-detects. Mean Aroclor 1268 concentrations at the end of the test ranged from less than 0.18 µg/g dw to 1.58 µg/g dw. However, individual replicates of oysters (with the exception of one replicate at station 4 that accumulated 2.73 µg/g) either contained less than 0.18 µg/g or 0.13-0.46 µg/g Aroclor 1268).

Oysters at the reference stations did not contain detectable concentrations of Aroclor 1268 after the 62-day deployment period. The highest concentrations were measured in oysters deployed at Station 4. Oysters at all site stations except stations 6, 7, and 9 accumulated Aroclor 1268 during the deployment period.

The PCB data were suitable for parametric analyses after rankit transformation. The results of the ANOVA indicated significant differences between stations ($p = 0.0008$); the Bonferroni test indicated that Aroclor 1268 was significantly higher at test Stations 3, 4 and 5 when compared to the two reference stations. The site stations were compared to each other with the Newman-Keuls test (Appendix A).

The Aroclor 1268 content increased in oysters only at Stations 3, 4, 5, 8 and 10 during the 62-day deployment period. The lowest Aroclor 1268 content was found in oysters at the reference stations; the highest content was found in oysters at Station 4.

The Aroclor 1268 content data was suitable for parametric analyses with rankit transformation. The results of the ANOVA indicated significant differences between stations ($p =0.02326$). The Bonferroni multiple contrast analysis indicated no significant differences between reference stations and stations near the LCP facility. However, the Newman-Keuls multiple range test indicates that Aroclor 1268 content at Stations 6 and 9 were significantly lower than at Station 4 (Appendix A).

Aroclor 1268 concentrations and content in caged oysters generally decline with distance from the head of the LCP ditch (Figure 3.32). Normalizing concentrations and content to lipid content reduces differences between sites except at station 4, where concentrations and content are still elevated.

3.7.3 Lead

Total lead concentration at the start of the test by station was estimated at 0.5 µg/g dw. This estimate was based on the total lead concentration measured for the 150 animals used for time zero, test initiation (T_0) tissue chemistry analyses. Mean total lead concentrations by station ranged from 0.8 to 1.40 µg/g dw at the end of the test. The lowest total lead

concentrations were measured in oysters deployed at Station 9; the highest concentrations were measured in oysters deployed at Station 3. Lead was accumulated by oysters deployed at both reference stations; the concentrations measured in reference oysters at the end of the test were among the highest measured during the caged oyster study.

The total lead concentration data were suitable for parametric analyses without transformation. No significant differences were found between stations in lead concentrations ($p>0.05$).

Total lead content per individual at the start of the test was 0.20 mg. The lead content increased in oysters at all stations during the 62-day deployment period. The lowest lead content was found in oysters at the reference stations and Station 6; the highest content was found in oysters at Station 3.

The total lead content data were suitable for parametric analyses with log transformation. The results of the ANOVA indicated significant differences between stations ($p=0.011048$). The Bonferroni multiple contrast analysis indicated no significant differences between reference stations and stations near the LCP facility. However, the Newman-Keuls multiple range test indicates that lead content at Stations 3 and 4 were significantly higher than at Station 9.

No relationship is apparent between oyster concentrations or content and distance from the head of the LCP ditch.

3.7.4 Comparison with Resident Oysters

Tissues of resident oysters collected from Stations 4, 5, and 10 were analyzed for total lead, total mercury, methylmercury, and Aroclor 1016, 1221, 1232, 1242, 1248, 1254, 1260, and 1268. The concentration of each chemical measured in resident oyster tissues

are provided in Table 3.10. In nearly all cases the resident oysters were found to have lower concentrations of total mercury, lead, and Aroclor 1268 than the caged oysters. Exceptions were seen at Station 10 where resident oysters had slightly higher concentrations of total mercury and Aroclor 1268 (Figures 3.12-3.15). Methylmercury concentrations were very similar between caged oysters and resident oysters. Other Aroclors were not detected in resident oysters with detection limits that ranged from 0.18 to 0.3 µg/g dw.

Table 3.1.a. High Water Chemistry - Unfiltered

	Station									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Total Suspended Solids (mg/L)	200	234	34	38	18	47	56	42	58	50
Ammonia (mg/L) ND = < 0.05 mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Lead (ug/L) ND = < 2 ug/L	ND	11	ND	ND	ND	ND	ND	ND	ND	ND
Total Mercury (ng/L)	26	23	71	136	32	45	63	56	53	26
Total Manganese (ug/L) NA = not analyzed	82	358	90	86	59	87	NA	97	111	110
Total Iron (ug/L) NA = not analyzed	4280	11000	795	1000	573	868	NA	1150	1270	1260
PCB Aroclor 1268 (ug/L) ND = < 0.2 ug/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 3.1.b. High Water Chemistry - Filtered

	Station									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Dissolved Organic Carbon (mg/L)	5.0	4.7	4.5	4.7	4.4	4.3	4.3	4.4	4.3	3.9
Dissolved Lead (ug/L) ND = < 2 ug/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dissolved Mercury (ng/L) ND =< 5 ng/L	ND	ND	8	ND	5	6	7	10	30	7
Dissolved Manganese (ug/L)	28	70	42	9	16	9	13	11	7	7
Dissolved Iron (ug/L)	75	151	225	112	144	103	156	132	104	104

Table 3.1.c. Low Water Chemistry - Unfiltered

	Station									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Total Suspended Solids (mg/L)	65	49	25	46	1350	84	90	97	58	7
Ammonia (mg/L) ND = < 0.05 mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Lead (ug/L) ND = < 2 ug/L	ND	ND	ND	ND	20	ND	5	ND	ND	ND
Total Mercury (ng/L) ND = < 5 ng/L	ND	ND	341	398	114	159	203	95	46	43
Monomethyl Mercury (ng/L)					14.4				3.94	2.31
Percent Monomethyl Mercury					12.63				8.57	5.37
Total Manganese (ug/L)	428	498	1150	1020	1400	1530	1080	916	399	78

Table 3.1.c. Low Water Chemistry - Unfiltered (cont.)

	Station									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Total Iron (ug/L)	1560	1210	600	1140	11200	2680	4440	1760	905	529
PCB Aroclor 1268 (ug/L)	ND	ND	0.7	1.0	5.5	ND	0.3	ND	ND	ND

ND = < 0.2 ug/L

Table 3.1.d. Low Water Chemistry - Filtered

	Station									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Dissolved Organic Carbon (mg/L)	5.1	5.4	20.5	9.9	8.7	10.2	9.5	10	6.4	5.3
Dissolved Lead (ug/L) ND = < 2 ug/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dissolved Mercury (ng/L) ND = < 5 ng/L	ND	ND	82	135	94	20	34	33	12	7
Dissolved Monomethyl Mercury (ng/L)					4.29				0.671	0.414
Percent Dissolved Monomethyl Mercury					4.56				5.59	5.91
Dissolved Manganese (ug/L)	363	391	1080	874	1000	1280	982	873	316	29
Dissolved Iron (ug/L)	489	197	366	322	154	435	204	314	150	126

Table 3.2. Bank Sediment Chemistry

		Station									
		1	2	3	4	5	6	7	8	9	10
Percent											
Total	Rep 1	3.67	4.26	7.00	5.36	3.49	5.64	5.21	5.45	3.71	2.84
Organic	Rep 4	3.73	5.50	8.43	5.51	2.51	5.44	5.26	5.44	4.69	4.65
Carbon	Rep 7	3.56	4.85	5.65	5.59	4.14	5.83	5.31	5.32	4.76	4.52
	Mean	3.65	4.87	7.03	5.49	3.38	5.64	5.26	5.40	4.39	4.00
	Std. Dev	0.09	0.62	1.39	0.12	0.82	0.20	0.05	0.07	0.59	1.01
Total	Rep 1	33 J	40 J	720 J	78	660	90	220	140	470	41
Sulfides	Rep 4	14 J	410 J	230 J	760	440	190	100	100	98	110
(mg/kg)	Rep 7	200 J	97 J	1400 J	1100	250	69	100	39	140	44
	Mean	82	182	783	646	450	116	140	93	236	65
	Std. Dev	102	199	588	520	205	65	69	51	204	39
Percent	Rep 1	84.3	86.2	96.1	96.3	53.4	94.7	99.3	96.6	78.8	59.8
Fines	Rep 4	88.5	81.9	98.9	99.1	42.4	98.3	101.7	97.1	112.2	92.6
	Rep 7	90.4	86.7	92.7	101.6	62.4	94.0	95.1	92.6	97.1	88.3
	Mean	87.7	84.9	95.9	99.0	52.7	95.7	98.7	95.4	96.0	80.2
	Std. Dev	3.1	2.6	3.1	2.7	10.0	2.3	3.3	2.5	16.7	17.8
Total	Rep 1	11	10	20	29	58	23	19	20	16	13
Lead	Rep 4	11	9	22	33	53	22	18	20	20	17
(mg/kg-dry)	Rep 7	11	11	28	35	34	25	20	20	18	18
	Mean	11	10	23	32	48	23	19	20	18	16
	Std. Dev	0	1	4	3	13	2	1	0	2	3
Total	Rep 1	13	12	21	30	109	24	19	21	20	22
Lead (mg/kg-dry)	Rep 4	12	11	22	33	125	22	18	21	18	18
(norm. to % fines)	Rep 7	12	13	30	34	54	27	21	22	19	20
	Mean	13	12	24	33	96	24	19	21	19	20
	Std. Dev	0	1	5	2	37	2	2	1	1	2

Table 3.2. Bank Sediment Chemistry (cont.) (note altered units for methyl mercury)

		Station									
		1	2	3	4	5	6	7	8	9	10
Total Mercury (mg/kg-dry)	Rep 1	0.050	0.040	16.40	8.17	8.02	1.93	1.26	1.08	1.64	0.42
	Rep 4	0.050	0.050	8.89	10.20	7.52	1.36	1.10	0.86	1.35	0.94
	Rep 7	0.050	0.050	12.70	7.32	20.40	1.95	1.16	0.97	1.34	0.90
	Mean	0.050	0.047	12.66	8.56	11.98	1.75	1.17	0.97	1.44	0.75
	Std. Dev	0.000	0.006	3.76	1.48	7.30	0.34	0.08	0.11	0.17	0.29
Total Mercury (mg/kg dry)	Rep 1	0.059	0.046	17.07	8.48	15.02	2.04	1.27	1.12	2.08	0.70
	Rep 4	0.056	0.061	8.99	10.29	17.74	1.38	1.08	0.89	1.20	1.02
	Rep 7	0.055	0.058	13.70	7.20	32.69	2.07	1.22	1.05	1.38	1.02
(norm. to % fines)	Mean	0.057	0.055	13.25	8.66	21.82	1.83	1.19	1.02	1.55	0.91
	Std. Dev	0.002	0.008	4.06	1.55	9.52	0.39	0.10	0.12	0.46	0.18
Methyl Mercury (ug/kg-dry)	Rep 4	0.486*	0.608*	57.400*	32.700*	4.950*	13.100*	9.930*	11.600*	20.100*	8.370*
Percent Methyl Mercury	Rep 4	0.970	1.220	0.650	0.320	0.070	0.960	0.900	1.350	1.490	0.890
PCB Aroclor 1268 (mg/kg-dry)	Rep 1	ND	ND	57.0 J	18.0	89.0	6.3	3.1	2.4	3.6	2.2
	Rep 4	ND	ND	25.0	27.0	17.0	5.3	2.5	1.8	1.5	4.4
	Rep 7	ND	ND	35.0 J	20.0	43.0	6.8	2.9	3.0	1.6	2.1
ND = < 0.028 mg/kg	Mean	0.014**	0.014**	39.0	21.7	49.7	6.1	2.8	2.4	2.2	2.9
	Std. Dev	0.0	0.0	16.4	4.7	36.5	0.8	0.3	0.6	1.2	1.3
PCB Aroclor 1268 (normalized to %fines and TOC)	Rep 1	ND	ND	847.3	348.7	4775.5	118.0	59.9	45.6	123.1	129.5
	Rep 4	ND	ND	299.9	494.5	1597.4	99.1	46.9	34.1	28.5	102.2
	Rep 7	ND	ND	668.3	352.1	1664.5	124.1	57.4	60.9	34.6	52.6
	Mean	0.437**	0.342**	605.1	398.4	2679.1	113.7	54.8	46.9	62.1	94.8
	Std. Dev	0.015	0.036	279.1	83.2	1815.9	13.0	6.9	13.5	53.0	39.0

*All samples blank corrected by 0.004 - 0.045 ug/kg

** Mean values calculated using 1/2 detection limit

Table 3.3. Creek Sediment Chemistry (cont.) (note altered units for methyl mercury)

		Station									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Total	Rep 1	0.010	0.030	16.80	60.50	9.19	2.16	3.45	2.50	1.50	1.36
Mercury	Rep 4	0.005	0.020	11.70	61.80	50.10	1.84	2.30	1.73	2.13	1.33
(mg/kg-dry)	Rep 7	0.010	0.030	0.10	72.80	12.60	1.70	2.17	2.23	1.90	2.61
	Mean	0.008	0.027	9.53	65.03	23.96	1.90	2.64	2.15	1.84	1.77
	Std. Dev	0.003	0.006	8.56	6.76	22.70	0.24	0.70	0.39	0.32	0.73
Total	Rep 1	0.063	0.066	20.44	74.69	11.29	2.20	3.43	2.53	2.26	1.46
Mercury	Rep 4	0.049	0.088	12.77	70.23	52.46	1.82	2.46	1.86	2.14	1.72
(mg/kg dry)	Rep 7	0.071	0.055	0.10	90.43	16.89	1.82	2.28	2.39	1.96	2.73
(norm. to % fines)	Mean	0.061	0.070	11.10	78.45	26.88	1.94	2.72	2.26	2.12	1.97
	Std. Dev	0.011	0.017	10.27	10.62	22.33	0.22	0.62	0.36	0.15	0.67
Methyl Mercury (ug/kg-dry)	Rep 4	0.052*	0.105*	5.950*	18.500*	2.940*	0.825*	5.570*	1.080*	10.000*	2.990*
Percent Methyl Mercury	Rep 4	1.040	0.525	0.051	0.030	0.006	0.045	0.242	0.062	0.469	0.225
PCB	Rep 1	ND	ND	78.0	190.0 J	49.0	3.0	4.1	5.4	4.2	2.2
Aroclor 1268	Rep 4	ND	ND	110.0 J	110.0 J	96.0	1.8	6.8 J	5.5 J	2.5	9.4
(mg/kg-dry)	Rep 7	ND	ND	0.295	99.0 J	62.0	5.4 J	5.2 J	4.4	7.3	22.0
ND = < 0.028 mg/kg	Mean	0.014**	0.014**	62.8	133.0	69.0	3.4	5.4	5.1	4.7	11.2
	Std. Dev	0.0	0.0	56.4	49.7	24.3	1.8	1.4	0.6	2.4	10.0
PCB	Rep 1	ND	ND	1506.2	4319.9	1286.3	50.8	76.0	105.5	190.8	53.5
Aroclor 1268	Rep 4	ND	ND	2261.5	1935.0	1798.3	35.4	122.6	108.5	54.1	350.4
(normalized to % fines	Rep 7	ND	ND	7.08	2364.5	1699.6	111.6	86.5	80.7	165.4	512.0
and TOC)	Mean	20.5**	1.8**	1258.3	2873.1	1594.7	65.9	95.0	98.2	136.8	305.3
	Std. Dev	7.6	0.7	1147.5	1271.2	271.6	40.3	24.5	15.3	72.7	232.5

*All samples blank corrected by 0.004 - 0.045 ug/kg

** Mean values calculated using 1/2 detection limit

Table 3.3. Creek Sediment Chemistry (cont.) (note altered units for methyl mercury)

		Station									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Total	Rep 1	0.010	0.030	16.80	60.50	9.19	2.16	3.45	2.50	1.50	1.36
Mercury	Rep 4	0.005	0.020	11.70	61.80	50.10	1.84	2.30	1.73	2.13	1.33
(mg/kg-dry)	Rep 7	0.010	0.030	0.10	72.80	12.60	1.70	2.17	2.23	1.90	2.61
	Mean	0.008	0.027	9.53	65.03	23.96	1.90	2.64	2.15	1.84	1.77
	Std. Dev	0.003	0.006	8.56	6.76	22.70	0.24	0.70	0.39	0.32	0.73
Total	Rep 1	0.063	0.066	20.44	74.69	11.29	2.20	3.43	2.53	2.26	1.46
Mercury	Rep 4	0.049	0.088	12.77	70.23	52.46	1.82	2.46	1.86	2.14	1.72
(mg/kg dry)	Rep 7	0.071	0.055	0.10	90.43	16.89	1.82	2.28	2.39	1.96	2.73
(norm. to % fines)	Mean	0.061	0.070	11.10	78.45	26.88	1.94	2.72	2.26	2.12	1.97
	Std. Dev	0.011	0.017	10.27	10.62	22.33	0.22	0.62	0.36	0.15	0.67
Methyl Mercury (ug/kg-dry)	Rep 4	0.052*	0.105*	5.950*	18.500*	2.940*	0.825*	5.570*	1.080*	10.000*	2.990*
Percent Methyl Mercury	Rep 4	1.040	0.525	0.051	0.030	0.006	0.045	0.242	0.062	0.469	0.225
PCB	Rep 1	ND	ND	78.0	190.0 J	49.0	3.0	4.1	5.4	4.2	2.2
Aroclor 1268	Rep 4	ND	ND	110.0 J	110.0 J	96.0	1.8	6.8 J	5.5 J	2.5	9.4
(mg/kg-dry)	Rep 7	ND	ND	0.295	99.0 J	62.0	5.4 J	5.2 J	4.4	7.3	22.0
ND = < 0.028 mg/kg	Mean	0.014**	0.014**	62.8	133.0	69.0	3.4	5.4	5.1	4.7	11.2
	Std. Dev	0.0	0.0	56.4	49.7	24.3	1.8	1.4	0.6	2.4	10.0
PCB	Rep 1	ND	ND	1506.2	4319.9	1286.3	50.8	76.0	105.5	190.8	53.5
Aroclor 1268	Rep 4	ND	ND	2261.5	1935.0	1798.3	35.4	122.6	108.5	54.1	350.4
(normalized to % fines	Rep 7	ND	ND	7.08	2364.5	1699.6	111.6	86.5	80.7	165.4	512.0
and TOC)	Mean	20.5**	1.8**	1258.3	2873.1	1594.7	65.9	95.0	98.2	136.8	305.3
	Std. Dev	7.6	0.7	1147.5	1271.2	271.6	40.3	24.5	15.3	72.7	232.5

*All samples blank corrected by 0.004 - 0.045 ug/kg

** Mean values calculated using 1/2 detection limit

Table 3.4. Fish Tissue Chemistry

		Station									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Total	Rep 1	0.17	0.26	0.27	0.19	0.19	0.26	0.13	0.27	0.10	0.10
Lead	Rep 2	0.14	0.24	0.19	0.14	0.30	0.19	0.18	0.64		0.12
(µg/g-dry)	Rep 3	0.87	0.29	0.21	0.21	0.14	0.17	0.15	0.25		0.10
	Mean	0.39	0.26	0.22	0.18	0.21	0.21	0.15	0.39	0.10	0.11
	Std. Dev.	0.41	0.03	0.04	0.04	0.08	0.05	0.02	0.22	0.00	0.01
Total	Rep 1	0.04	0.02	1.36	1.30	1.05	0.40	0.49	0.38	0.55	0.20
Mercury	Rep 2	0.04	0.01	1.10	1.20	0.79	0.34	0.42	0.37		0.20
(µg/g-dry)	Rep 3	0.04	0.02	1.07	1.16	1.01	0.42	0.37	0.39		0.25
	Mean	0.04	0.02	1.18	1.22	0.95	0.39	0.43	0.38	0.55	0.22
	Std. Dev.	0.00	0.01	0.16	0.07	0.14	0.04	0.06	0.01	0.00	0.03
Methyl	Rep 1	0.0266*	0.0183*	1.411*	1.259*	0.943*	0.423*	0.441*	0.388*	0.582*	0.244*
Mercury	Rep 2										0.286*
(µg/g-dry)	Rep 3										0.426*
	Mean										0.319
	Std. Dev.										0.095
Percent	Rep 1	66.50	91.50	103.75	96.85	89.81	105.75	90.00	102.11	105.82	123.23
Methyl	Rep 2										156.88
Mercury	Rep 3										169.65
	Mean										149.92
	Std. Dev.										23.98
PCB	Rep 1	ND	ND	15.75	85.71	14.96	3.83	2.44	1.57	1.55	0.65
Aroclor 1268	Rep 2	ND	ND	11.59	25.00	9.96	2.68	3.31	2.22		0.83
(µg/g-dry)	Rep 3	ND	ND	21.84	34.87	11.20	2.92	2.46	1.67		0.51
ND=<0.08 µg/g	Mean	0.04**	0.04**	16.39	48.53	12.04	3.14	2.74	1.82	1.55	0.66
	Std. Dev.	0.00	0.00	5.16	32.58	2.60	0.61	0.50	0.35	0.00	0.16

*All samples blank corrected by 4 ug/kg

**Mean values calculated using 1/2 detection limit

Table 3.4. Fish Tissue Chemistry (cont.)

	Station:	1	2	3	4	5	6	7	8	9	10
PCB	Rep 1	ND	ND	173.84	1166.12	***	40.66	153.46	16.42	19.16	6.56
Aroclor 1268	Rep 2	ND	ND	179.97	1838.24	240.00	29.94	39.03	100.91		9.42
Lipid Normalized	Rep 3	ND	ND	518.76	505.36	100.00	23.27	23.61	21.01		4.91
(µg/g lipid)	Mean	0.66**	0.63**	290.86	1169.91	170.00	31.29	72.03	46.11	19.16	6.96
	Std. Dev.	0.01	0.09	197.39	666.45	98.99	8.77	70.94	47.51	0.00	2.28
Percent	Rep 1	6.1	7.2	9.1	7.4	0.0	9.4	1.6	9.6	8.1	9.9
Lipids	Rep 2	6.7	5.5	6.4	1.4	4.2	9.0	8.5	2.2		8.8
(dry)	Rep 3	6.0	6.6	4.2	6.9	11.2	12.6	10.4	8.0		10.4
	Mean	6.3	6.4	6.6	5.2	5.1	10.3	6.8	6.6	8.1	9.7
	Std. Dev.	0.4	0.9	2.4	3.3	5.7	2.0	4.6	3.9	0.0	0.8
Percent	Rep 1	26.1	23.5	25.4	24.5	25.4	22.3	25.1	25.1	23.5	22.2
Solids	Rep 2	25.3	23.5	23.3	22.0	24.1	25.7	22.4	22.7		22.7
	Rep 3	26.7	25.9	26.1	26.1	25.0	26.3	24.0	23.9		23.1
	Mean	26.0	24.3	24.9	24.2	24.8	24.8	23.8	23.9	23.5	22.7
	Std. Dev.	0.7	1.4	1.5	2.1	0.7	2.2	1.4	1.2	0.0	0.5

*** Value not included since sample contained no detectable lipid

**Mean values calculated using 1/2 detection limit

Table 3.5. Fiddler Crab Tissue Chemistry

		Station									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Total Lead (µg/g-dry)	Rep 1	0.30	0.42			2.71	1.85	1.84	2.07	1.17	0.33 J
	Rep 2	0.34	0.42			1.97	2.11	1.28	1.58	1.06	0.41
	Rep 3	0.44	0.40			1.84	2.67	1.69	0.86	0.79	0.53
	Rep 4							1.08			
	Mean	0.36	0.41			2.17	2.21	1.47	1.50	1.01	0.42
	Std. Dev.	0.07	0.01			0.47	0.42	0.35	0.61	0.20	0.10
Total Mercury (µg/g-dry)	Rep 1	0.01	0.02	0.47	0.50	0.27	0.24	0.32	0.25	0.16	0.10
	Rep 2	0.02	0.02	0.43	0.32	0.23	0.26	0.30	0.32	0.14	0.13
	Rep 3	0.01	0.01	0.46	0.58	0.20	0.24	0.30	0.28	0.11	0.10
	Rep 4							0.29			
	Mean	0.01	0.02	0.45	0.47	0.23	0.25	0.30	0.28	0.14	0.11
	Std. Dev.	0.01	0.01	0.02	0.13	0.04	0.01	0.01	0.04	0.03	0.02
Methyl Mercury (µg/g-dry)	Rep 1	0.0116	0.0131	0.366	0.191	0.237	0.114	0.193	0.165	0.141	0.077
Percent Methyl Mercury	Rep 1	116.00	65.50	77.87	38.20	87.78	47.50	60.31	66.00	88.12	77.00
PCB Aroclor 1268 (µg/g-dry) ND=<0.06 µg/g	Rep 1	0.07	ND			5.41	0.25 J	0.59	2.10		1.68 J
	Rep 2	ND	ND			4.81	0.66	0.34	1.45		1.12 J
	Rep 3	ND	ND			5.04	0.55	0.66	2.08		1.29 J
	Rep 4						0.92				
	Mean	0.04*	0.03*			5.09	0.59	0.53	1.88		1.36
	Std. Dev.	0.02	0.00			0.30	0.28	0.17	0.37		0.29

*Mean values calculated using 1/2 detection limits

Table 3.5. Fiddler Crab Tissue Chemistry (cont.)

	Station:	1	2	3	4	5	6	7	8	9	10
PCB	Rep 1	ND	ND			158.19	4.84	17.05	37.17		19.77
Aroclor 1268	Rep 2	ND	ND			174.91	12.20	17.17	39.51		56.57
Lipid Normalized	Rep 3	ND	ND			169.70	12.88	15.28	45.02		***
(µg/g lipid)	Rep 4							32.18			
	Mean	1.33**	0.99**			167.60	9.97	20.42	40.57		38.17
	Std. Dev.	0.87	0.11			8.56	4.46	7.88	4.03		26.03
Percent	Rep 1	3.10	2.86			3.42	5.16	3.46	5.65		0.85
Lipids	Rep 2	3.38	2.83			2.75	5.41	1.98	3.67		1.98
(dry)	Rep 3	3.93	3.45			2.97	4.27	4.32	4.62		0.00
	Rep 4							2.85			
	Mean	3.47	3.05			3.05	4.95	3.15	4.65		0.94
	Std. Dev.	0.42	0.35			0.34	0.60	0.99	0.99		0.99
Percent	Rep 1	32.30	31.50	31.90	19.20	29.20	34.90	37.60	33.60	35.10	35.50
Solids	Rep 2	32.50	31.80	32.10	27.00	29.10	29.60	35.30	30.00	34.30	35.30
	Rep 3	33.10	29.00	37.40	31.10	33.70	32.80	32.40	30.30	33.40	34.80
	Mean	32.63	30.77	33.80	25.77	30.67	32.43	35.10	31.30	34.27	35.20
	Std. Dev.	0.42	1.54	3.12	6.05	2.63	2.67	2.61	2.00	0.85	0.36

*** Value not included since sample contained no detectable lipid

*Mean values calculated using 1/2 detection limits

Table 3.6 Oyster Tissue Chemistry - Concentration

		Caged Oysters											Resident Oysters		
	Station:	**Initial**	**1-Ref**	**2-Ref**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**4**	**5**	**10**
Total Lead (µg/g-dry)	Rep 1	0.44	0.67	0.75	1.35	1.39	1.28	0.87	0.86	1.09	0.84	1.14	0.80	0.81	1.16
	Rep 2	0.55	0.85	0.79	1.17	1.41	1.29	0.87	1.17	0.92	0.81	1.08	1.41	0.35	
	Rep 3		0.98	1.34	1.20			0.98	0.94	1.12	0.75	0.93	0.60	0.43	
	Mean	0.50	0.83	0.96	1.24	1.40	1.28	0.91	0.99	1.04	0.80	1.05	0.94	0.53	1.16
	Std. Dev.	0.08	0.16	0.33	0.10	0.01	0.01	0.06	0.16	0.11	0.04	0.11	0.42	0.25	0.00
Total Mercury (µg/g-dry)	Rep 1	0.16	0.13	0.12	4.12	3.20	2.41	6.19	2.43	2.41	1.27	1.12	2.81	2.28	2.36
	Rep 2	0.16	0.10	0.10	3.54	4.51	2.60	2.07	2.30	2.13	0.97	1.23	1.80	0.50	
	Rep 3	0.16	0.11	0.09	3.61			2.82	1.77	2.45	0.87	1.19	2.33	0.47	
	Mean	0.16	0.11	0.10	3.76	3.86	2.50	3.69	2.17	2.33	1.04	1.18	2.31	1.08	2.36
	Std. Dev.	0.00	0.02	0.02	0.32	0.93	0.13	2.19	0.35	0.17	0.21	0.06	0.50	1.04	0.00
Methyl Mercury (µg/g-dry)	Rep 1	0.18	0.07	0.10	2.86	2.74	2.11	1.29	1.09	0.95	0.96	1.10	1.76	1.75	1.67
Percent Methyl Mercury	Rep 1	112.50	53.85	83.33	69.42	85.62	87.55	20.84	44.86	39.42	75.59	98.21	62.63	76.84	70.76
PCB Aroclor 1268 (µg/g-dry)	Rep 1	ND	ND	ND	0.39	0.42	0.34	ND	ND	ND	ND	ND	0.47	0.34	0.41
	Rep 2	ND	ND	ND	0.30	2.73	0.36	ND	ND	0.46	ND	0.14	ND	ND	
	Rep 3	ND	ND	ND	0.32			ND	ND	ND		0.13	0.64	ND	
ND=<0.18 µg/g	Mean	0.05*	0.05*	0.05*	0.34	1.58	0.35	0.06*	0.06*	0.2*	0.06*	0.12*	0.4*	0.2*	0.41
	Std. Dev.	0.01	0.00	0.01	0.05	1.63	0.01	0.01	0.00	0.23	0.01	0.04	0.28	0.12	0.00
PCB Aroclor 1268 Lipid Norm (µg/g lipid)	Rep 1	ND	ND	ND	5.68	**	5.63	ND	ND	ND	ND	ND	4.31	4.66	5.16
	Rep 2	ND	ND	ND	4.42	45.96	6.00	ND	ND	6.99	ND	2.35	ND	ND	
	Rep 3	ND	ND	ND	4.51			ND	ND	ND		1.89	7.04	ND	
	Mean	0.05*	0.05*	0.05*	0.34	1.58	0.35	0.06*	0.06*	0.2*	0.06*	0.12*	0.4*	0.2*	0.41
	Std. Dev.	0.01	0.00	0.01	0.05	1.63	0.01	0.01	0.00	0.23	0.01	0.04	0.28	0.12	0.00

* - Mean value calculated using 1/2 detection limit.

** Value not included since sample contained no detectable lipids.

Table 3.6 Oyster Tissue Chemistry - Concentration (cont.)

		Caged Oysters											Resident Oysters		
	Station:	**Initial**	**1-Ref**	**2-Ref**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**4**	**5**	**10**
Percent Lipids (dry)	Rep 1	5.81	8.45	6.46	6.87	0	6.04	6.23	7.13	7.19	6.67	7.74	10.91	7.29	7.95
	Rep 2	5.26	6.48	7.14	6.79	5.94	6.00	6.08	6.67	6.58	5.78	5.96	1.80	5.56	
	Rep 3	5.71	7.96	7.45	7.09			6.20	7.96	6.18		6.87	9.09	4.03	
	Mean	5.59	7.63	7.02	6.92	2.97	6.02	6.17	7.25	6.65	6.22	6.86	7.27	5.63	7.92
	Std. Dev.	0.29	1.03	0.51	0.16	4.20	0.03	0.08	0.65	0.51	0.63	0.89	4.82	1.63	0.00
Percent Solids	Rep 1	17.20	18.10	16.40	15.00	14.00	14.40	16.70	15.70	13.90	14.70	15.90	11.00	8.23	8.84
	Rep 2	19.00	17.60	18.50	16.20	13.80	14.00	15.30	15.60	14.90	13.50	15.10	11.10	7.19	
	Rep 3	17.50	18.60	18.80	17.20			13.70	16.20	13.60	14.20	16.30	8.84	7.45	
	Mean	17.90	18.10	17.90	16.10	13.90	14.20	15.23	15.83	14.13	14.13	15.77	10.30	7.62	8.80
	Std. Dev.	1.00	0.50	1.30	1.10	0.14	0.28	1.50	0.32	0.68	0.60	0.61	1.30	0.54	0.00

Table 3.7 Oyster Tissue Chemistry - Content (note altered units for Hg and PCBs)

	Station:	Initial	1	2	3	4	5	6	7	8	9	10
Total Lead (mg/oyster)	Rep 1	0.17	0.37	0.33	0.51	0.42	0.40	0.33	0.37	0.40	0.34	0.36
	Rep 2	0.23	0.48	0.47	0.47	0.53	0.39	0.27	0.40	0.34	0.20	0.39
	Rep 3		0.60	0.86	0.52			0.32	0.31	0.37	0.20	0.36
	Mean	0.20	0.49	0.55	0.50	0.48	0.39	0.31	0.36	0.37	0.25	0.37
	Std. Dev.	0.04	0.12	0.28	0.02	0.08	0.01	0.03	0.04	0.03	0.08	0.02
Total Mercury (µg/oyster)	Rep 1	0.06	0.07	0.05	1.57	0.96	0.75	2.32	1.04	0.90	0.51	0.36
	Rep 2	0.07	0.06	0.06	1.43	1.71	0.78	0.65	0.78	0.79	0.24	0.44
	Rep 3	0.06	0.07	0.06	1.55			0.93	0.59	0.80	0.24	0.46
	Mean	0.06	0.07	0.06	1.52	1.34	0.77	1.30	0.81	0.83	0.33	0.42
	Std. Dev.	0.00	0.01	0.00	0.07	0.53	0.02	0.89	0.23	0.06	0.16	0.06
Methyl Mercury (µg/oyster)	Rep 1	0.07	0.04	0.05	1.25	0.81	0.64	0.39	0.48	0.34	0.37	0.36
Percent Methyl Mercury	Rep 1	111.56	56.31	95.53	79.61	84.38	85.29	17.03	46.13	38.51	72.85	100.52
PCB Aroclor 1268 (µg/oyster)	Rep 1	ND	ND	ND	0.15	0.13	0.11	ND	ND	ND	ND	ND
	Rep 2	ND	ND	ND	0.12	1.04	0.11	ND	ND	0.17	ND	0.05
	Rep 3	ND	ND	ND	0.14			ND	ND	ND		0.05
ND=<0.03 µg	Mean	0.02*	0.03*	0.03*	0.14	0.58	0.11	0.02*	0.02*	0.07*	0.02*	0.04*
	Std. Dev.	0.00	0.00	0.00	0.01	0.64	0.00	0.00	0.00	0.08	0.01	0.02

*Mean values calculated using 1/2 detection limits

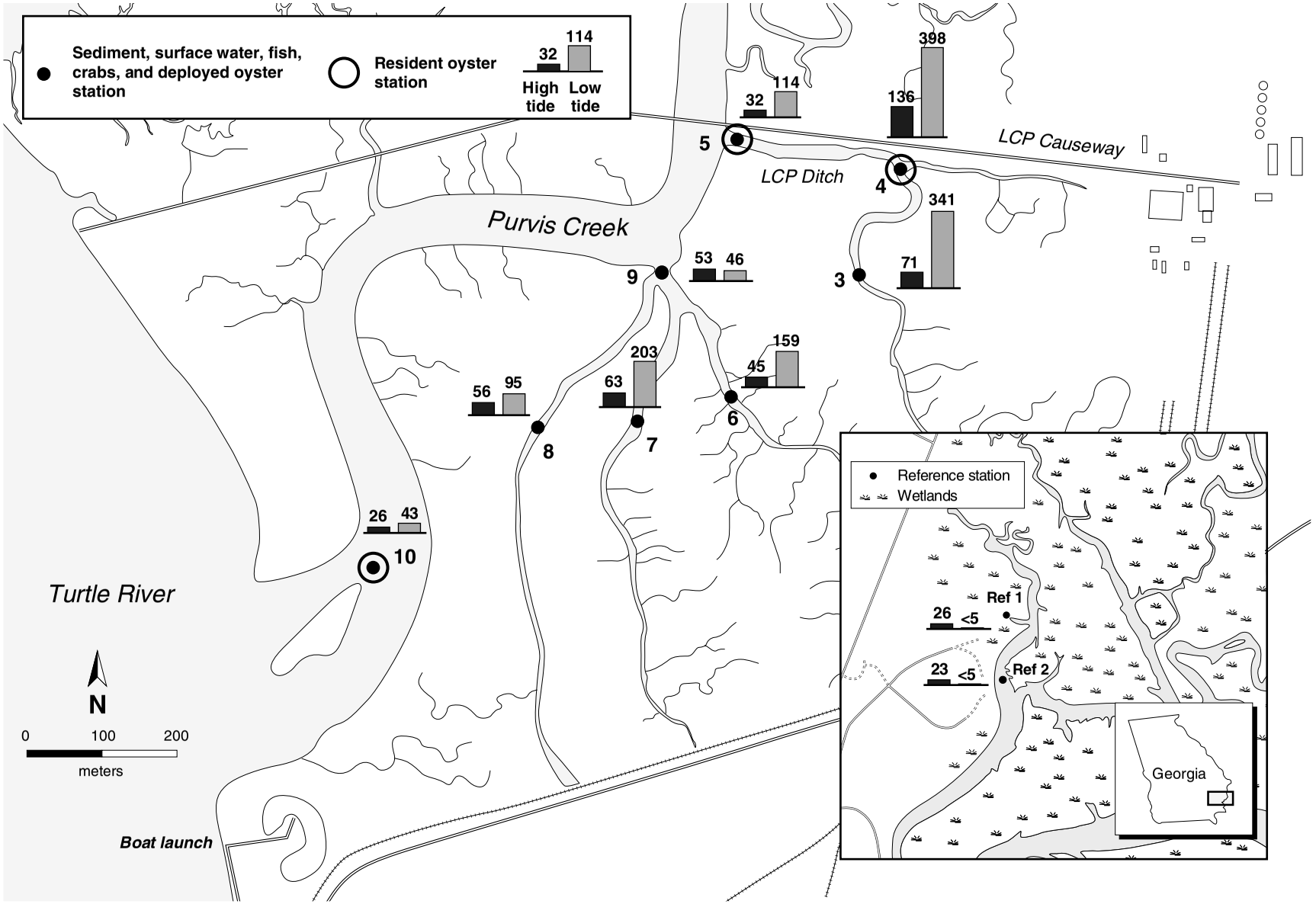


Figure 3.1. Mercury concentrations in unfiltered water (ng/L) n=1

Figure 3.2 Total mercury in low tide unfiltered water (ng/L) with distance from the head of the LCP ditch (station numbers indicated)

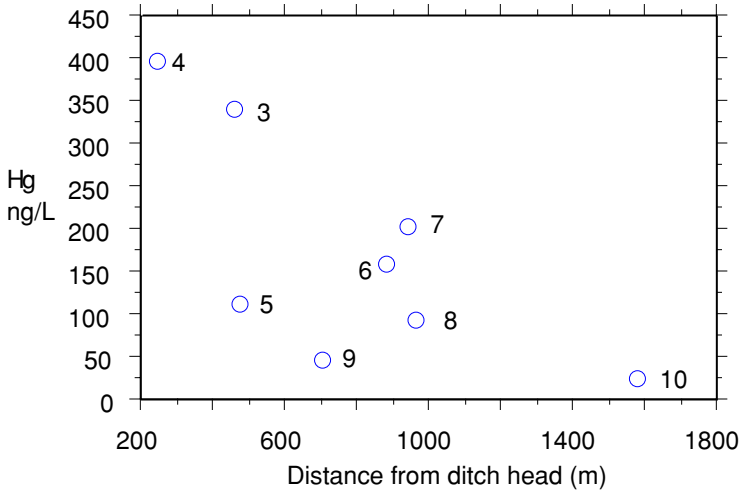
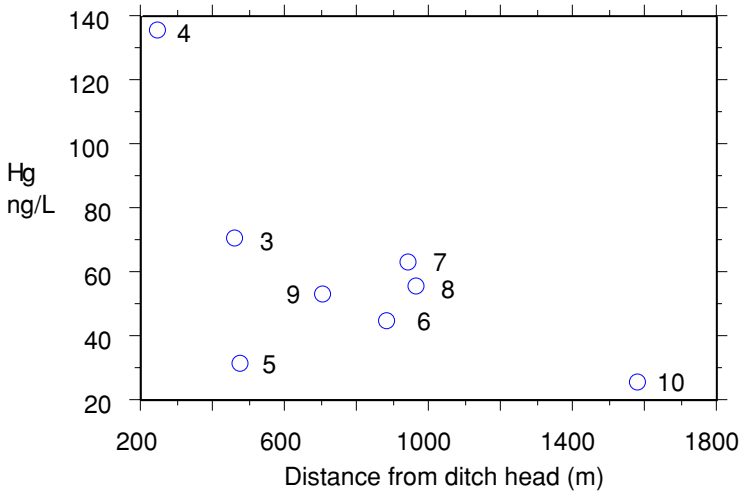


Figure 3.3 Total mercury in high tide unfiltered water (ng/L) with distance from the head of the LCP ditch (station numbers indicated)



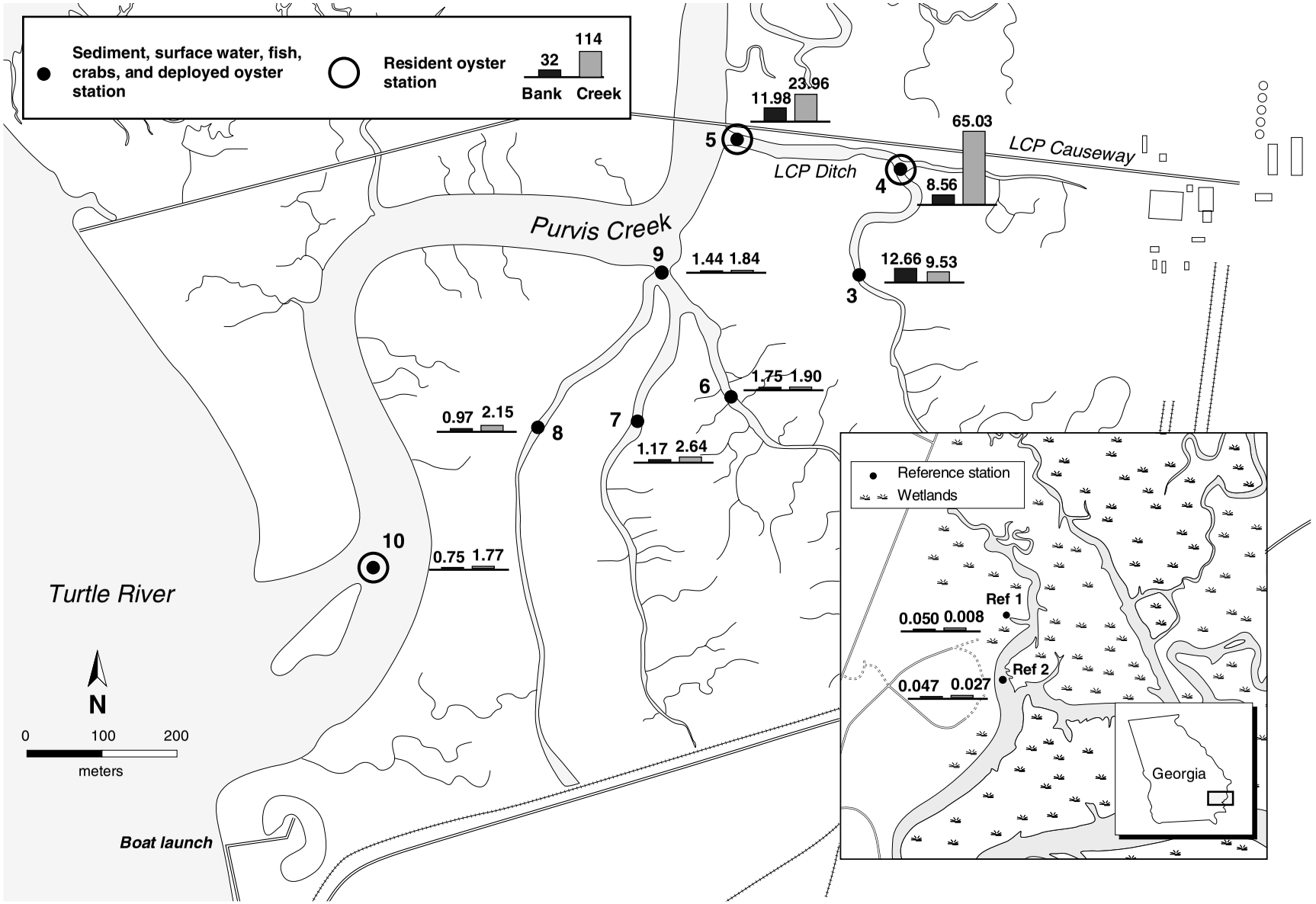


Figure 3.4. Mean bank and creek total Hg in sediment (mg/kg dry) n=3

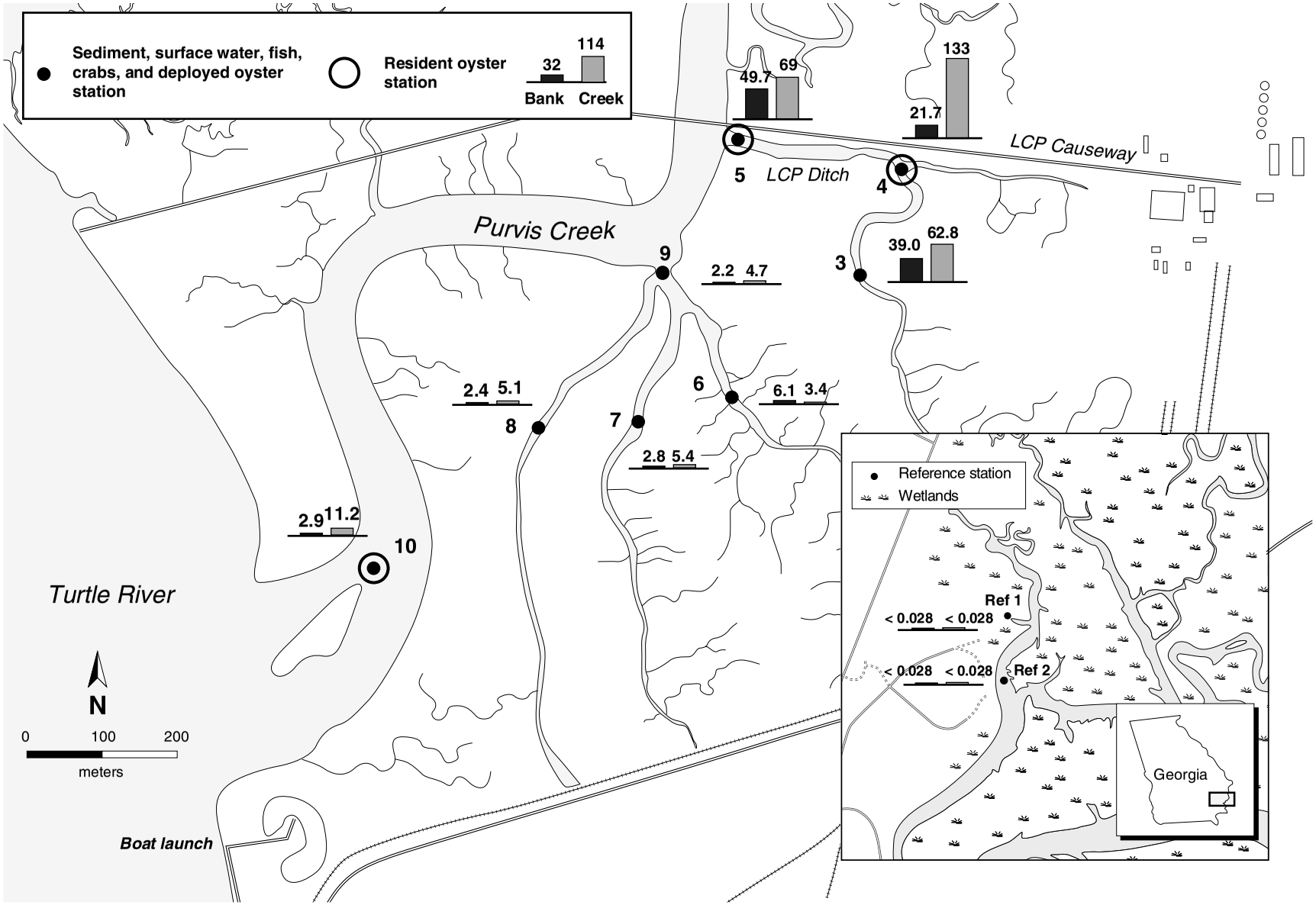


Figure 3.5. Mean bank and creek Aroclor 1268 in sediment (mg/kg dry) n=3

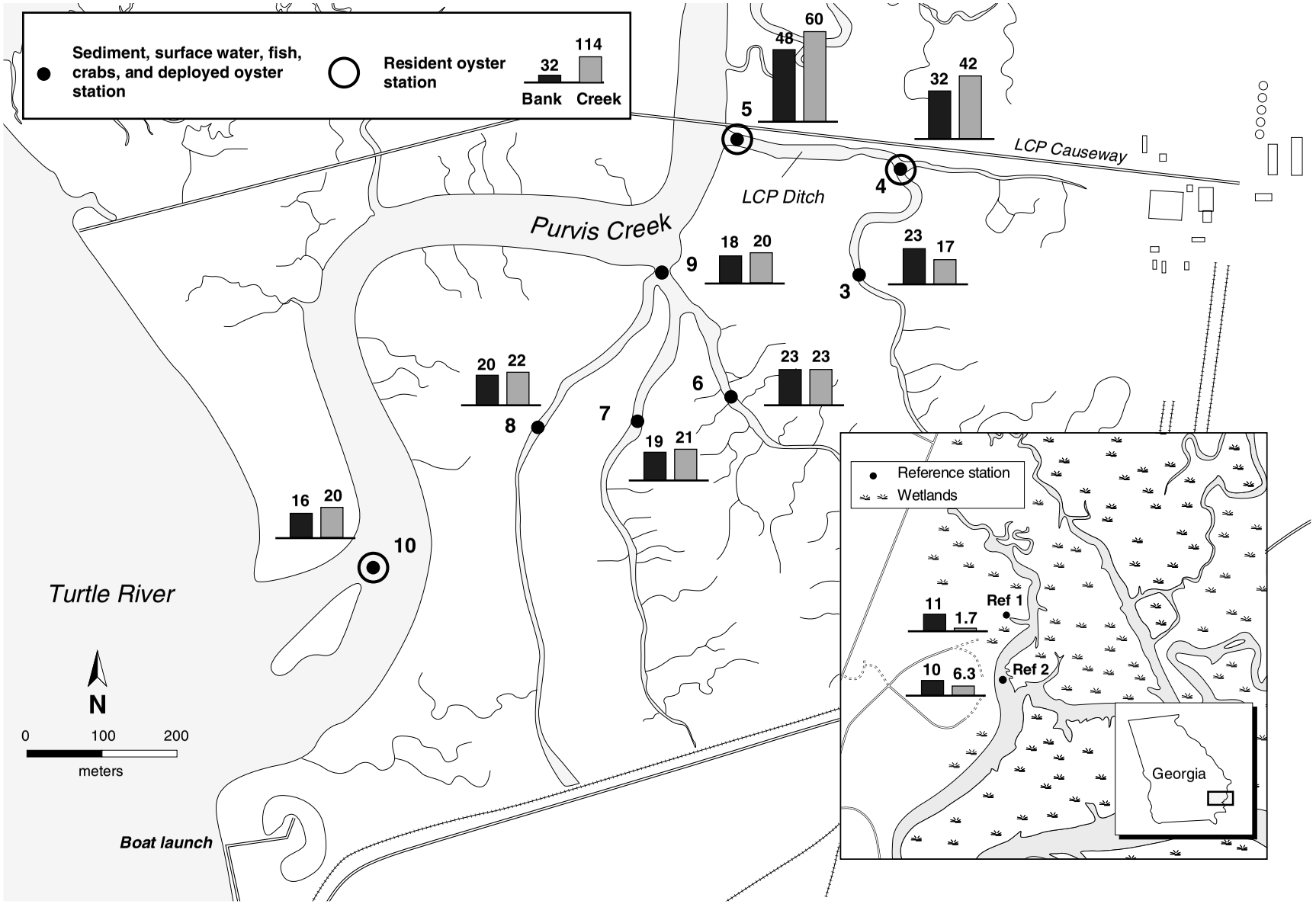


Figure 3.6. Mean bank and creek lead in sediment (mg/kg dry) n=3

Figure 3.7 Total mercury in bank sediment (mg/kg dry weight) with distance from the head of the LCP ditch (station numbers indicated)

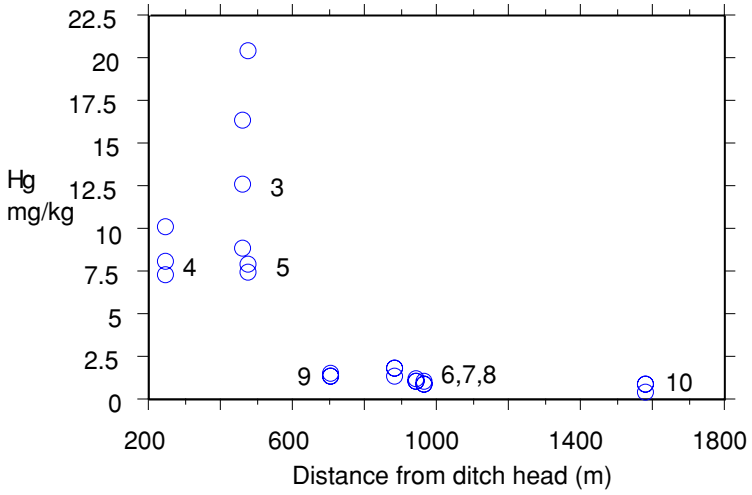


Figure 3.8 Total mercury in creek sediment (mg/kg dry weight) with distance from the head of the LCP ditch (station numbers indicated)

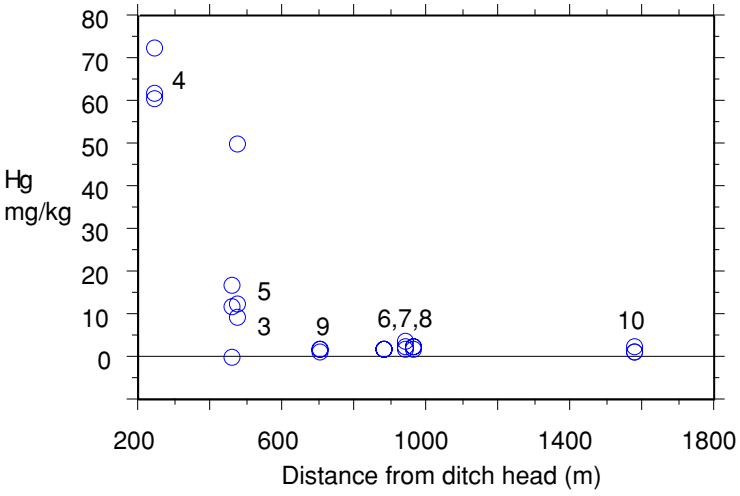


Figure 3.9 Aroclor 1268 in bank sediment (mg/kg dry weight) with distance from the head of the LCP ditch (station numbers indicated)

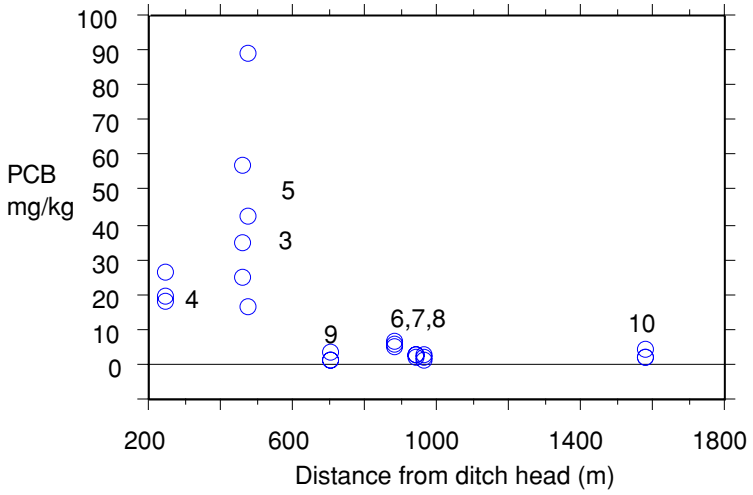


Figure 3.10 Aroclor 1268 in creek sediment (mg/kg dry weight) with distance from the head of the LCP ditch (station numbers indicated)

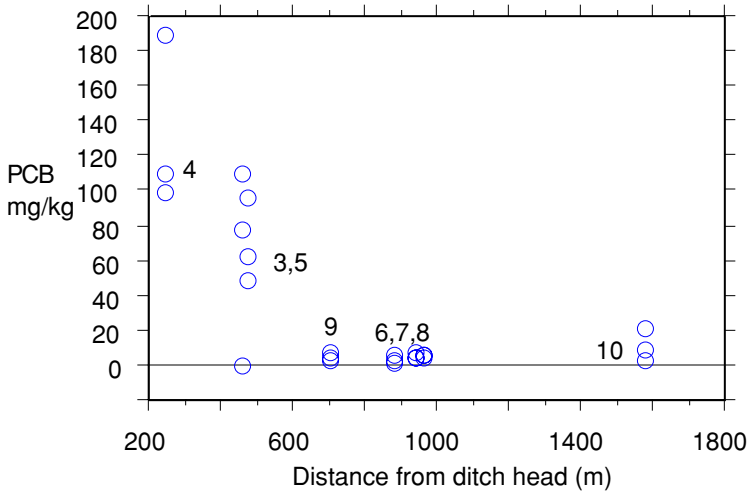


Figure 3.11 Lead in bank sediment (mg/kg dry weight) with distance from the head of the LCP ditch (station numbers indicated)

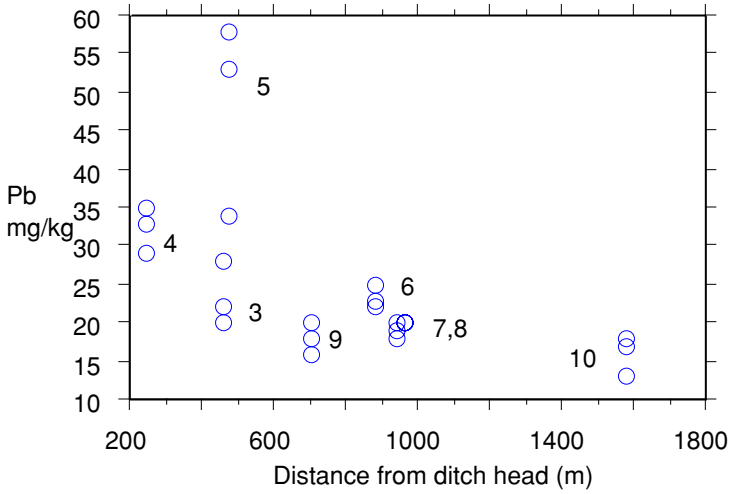
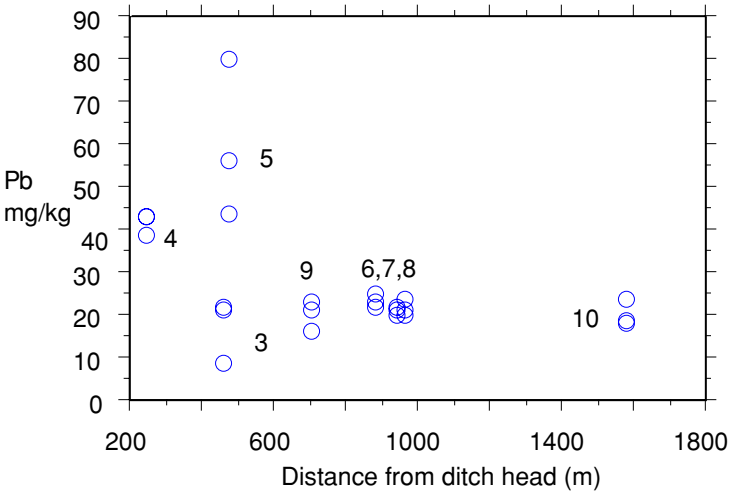


Figure 3.12 Lead in creek sediment (mg/kg dry weight) with distance from the head of the LCP ditch (station numbers indicated)



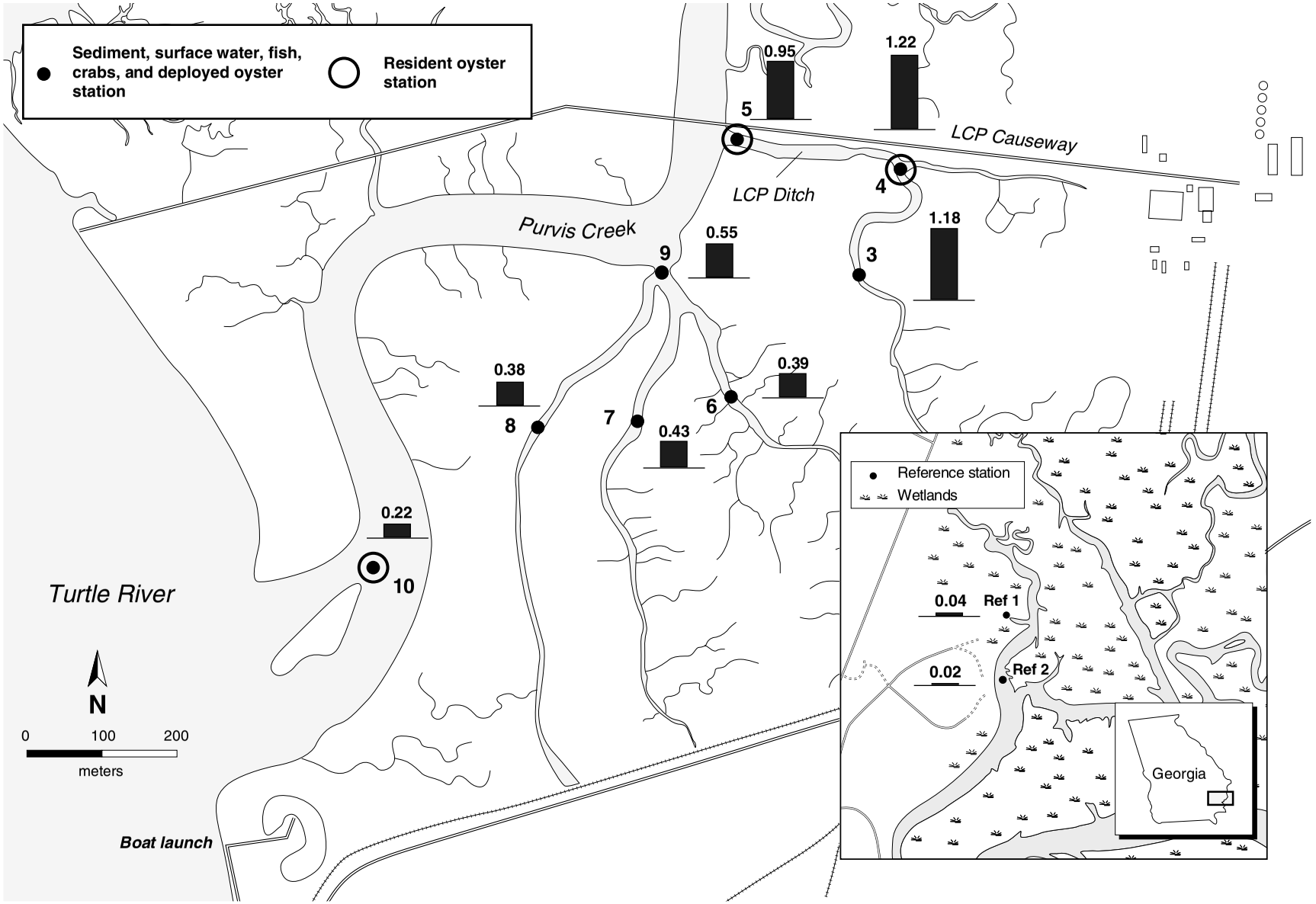


Figure 3.13. Mean total Hg in fish (g/g dry) n=3

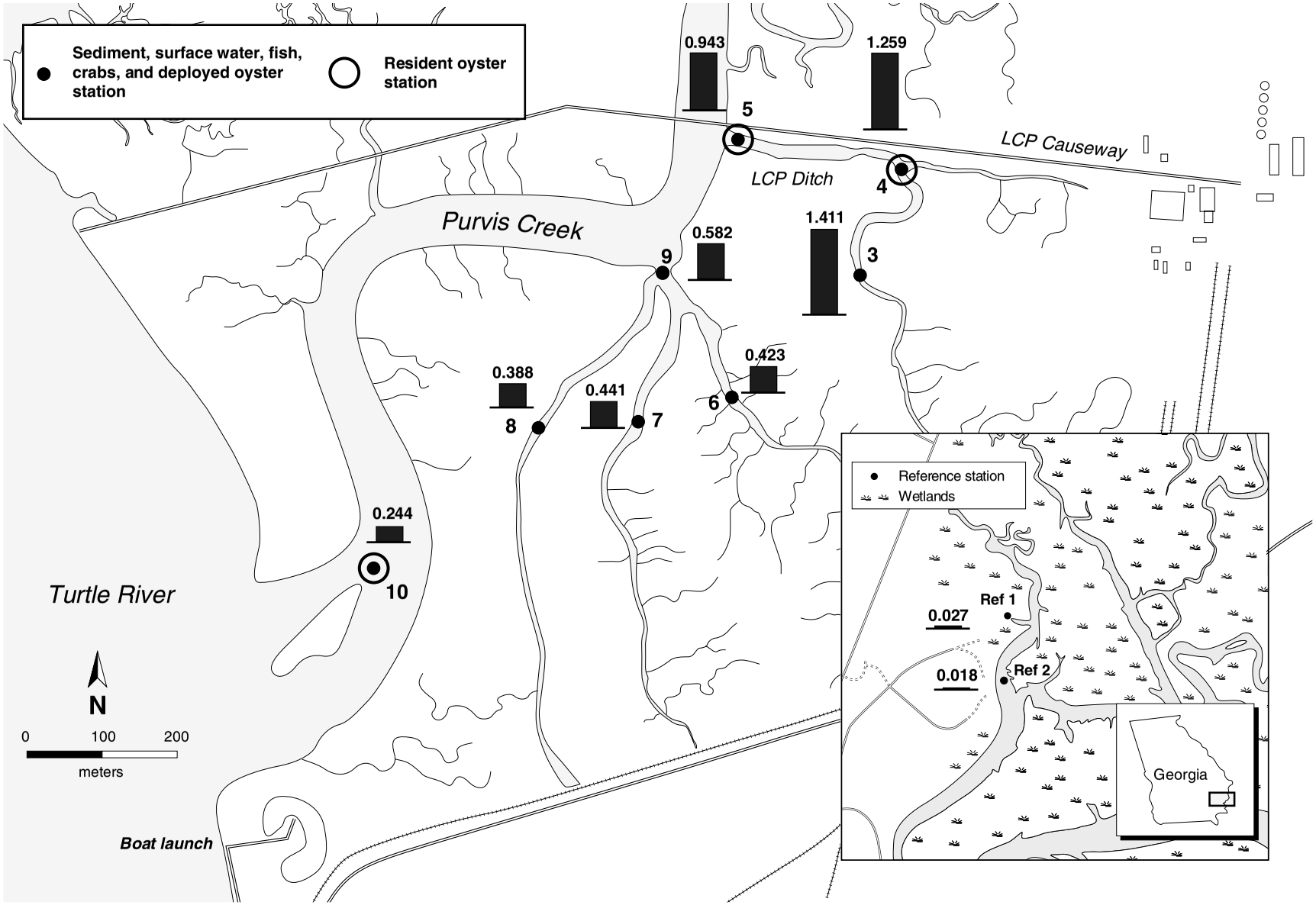


Figure 3.14. Methylmercury in fish (g/g dry) n=1

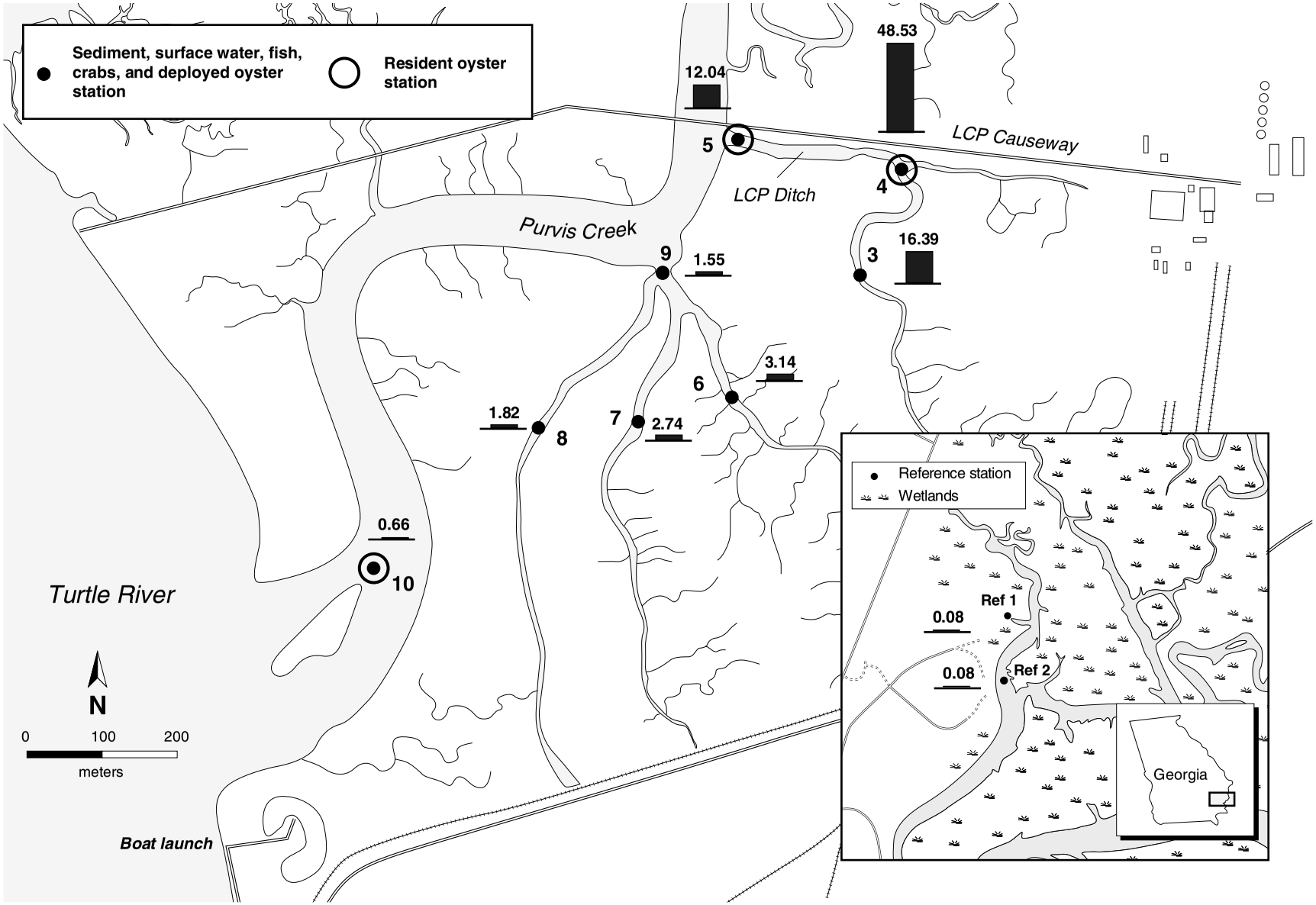


Figure 3.15. Mean Aroclor 1268 in fish (g/g dry) n=3

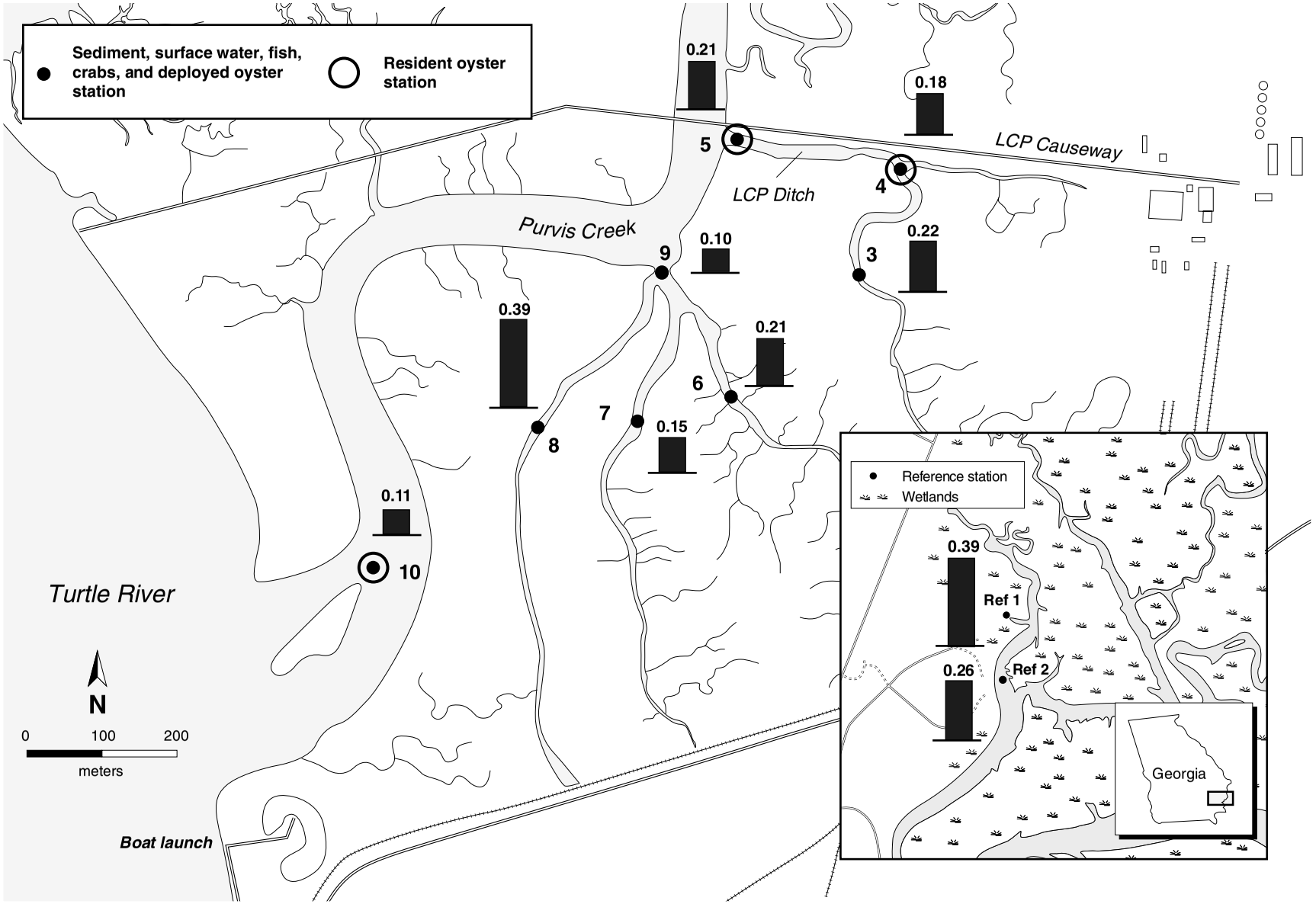


Figure 3.16. Mean lead in fish (g/g dry) n=3

Figure 3.17 Total mercury in fish (µg/g dry weight) with distance from the head of the LCP ditch (station numbers indicated)

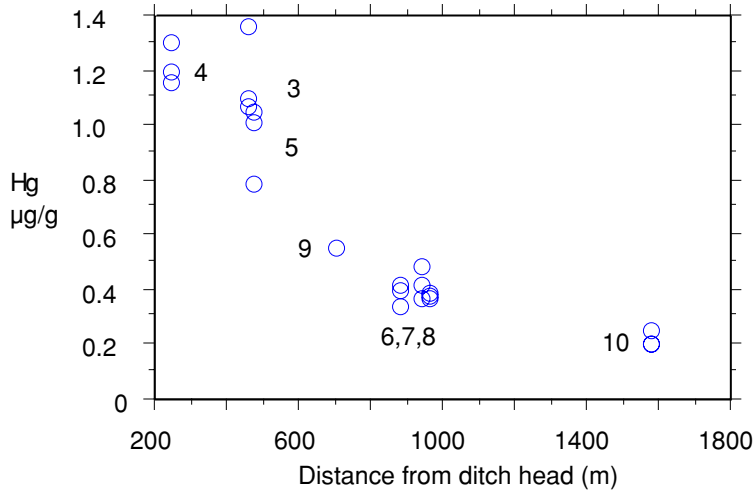


Figure 3.18 Aroclor 1268 in fish (µg/g dry weight) with distance from the head of the LCP ditch (station numbers indicated)

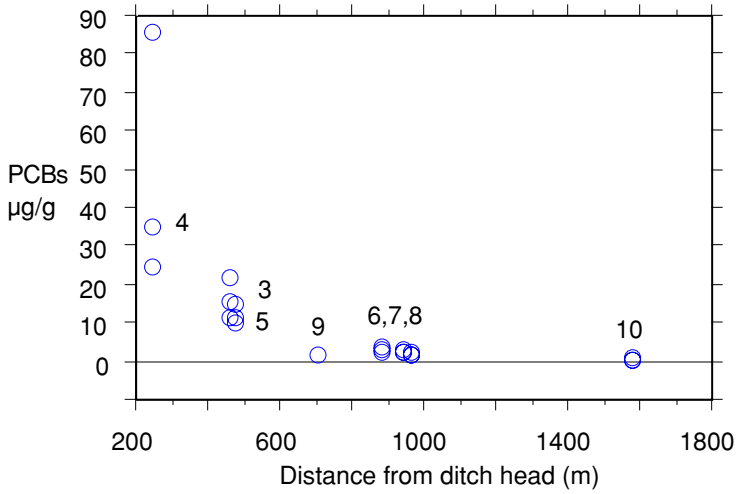
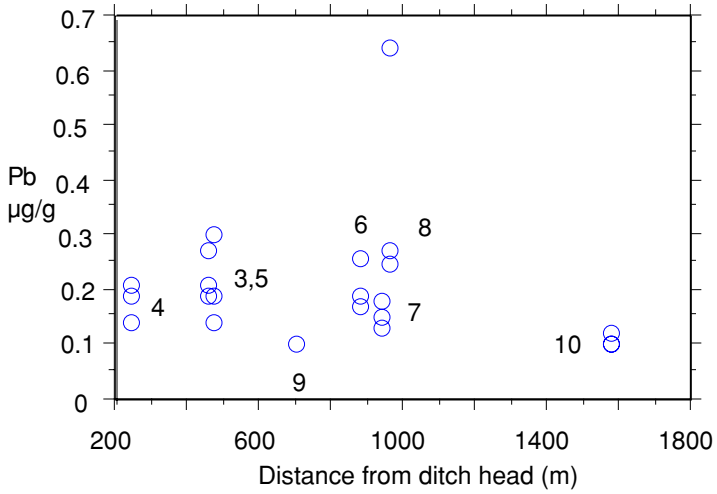


Figure 3.19 Lead in fish (µg/g dry weight) with distance from the head of the LCP ditch (station numbers indicated)



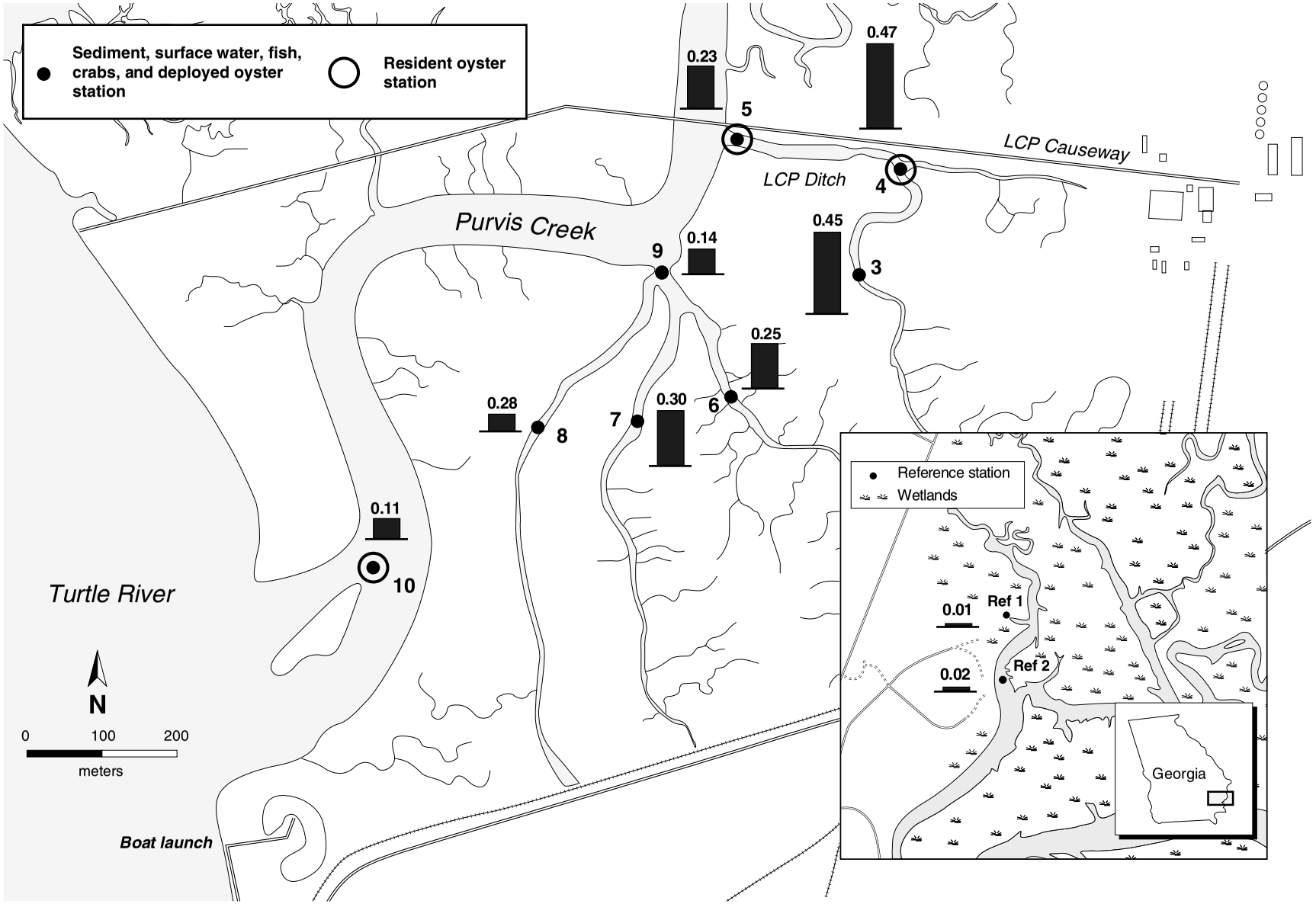


Figure 3.20. Mean total Hg in fiddler crab (g/g dry) n=3

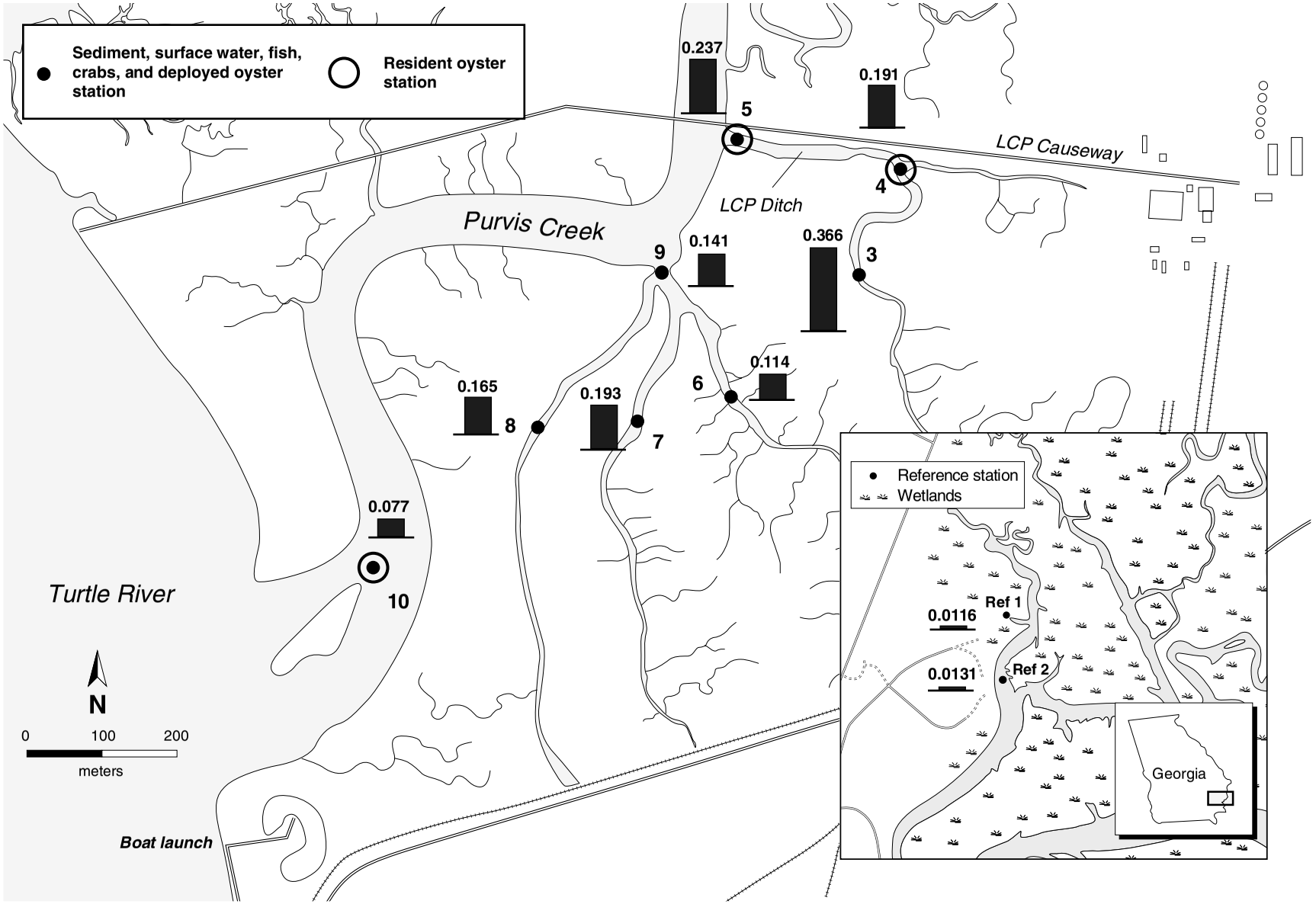


Figure 3.21. Methylmercury in fiddler crab (g/g dry) n=1

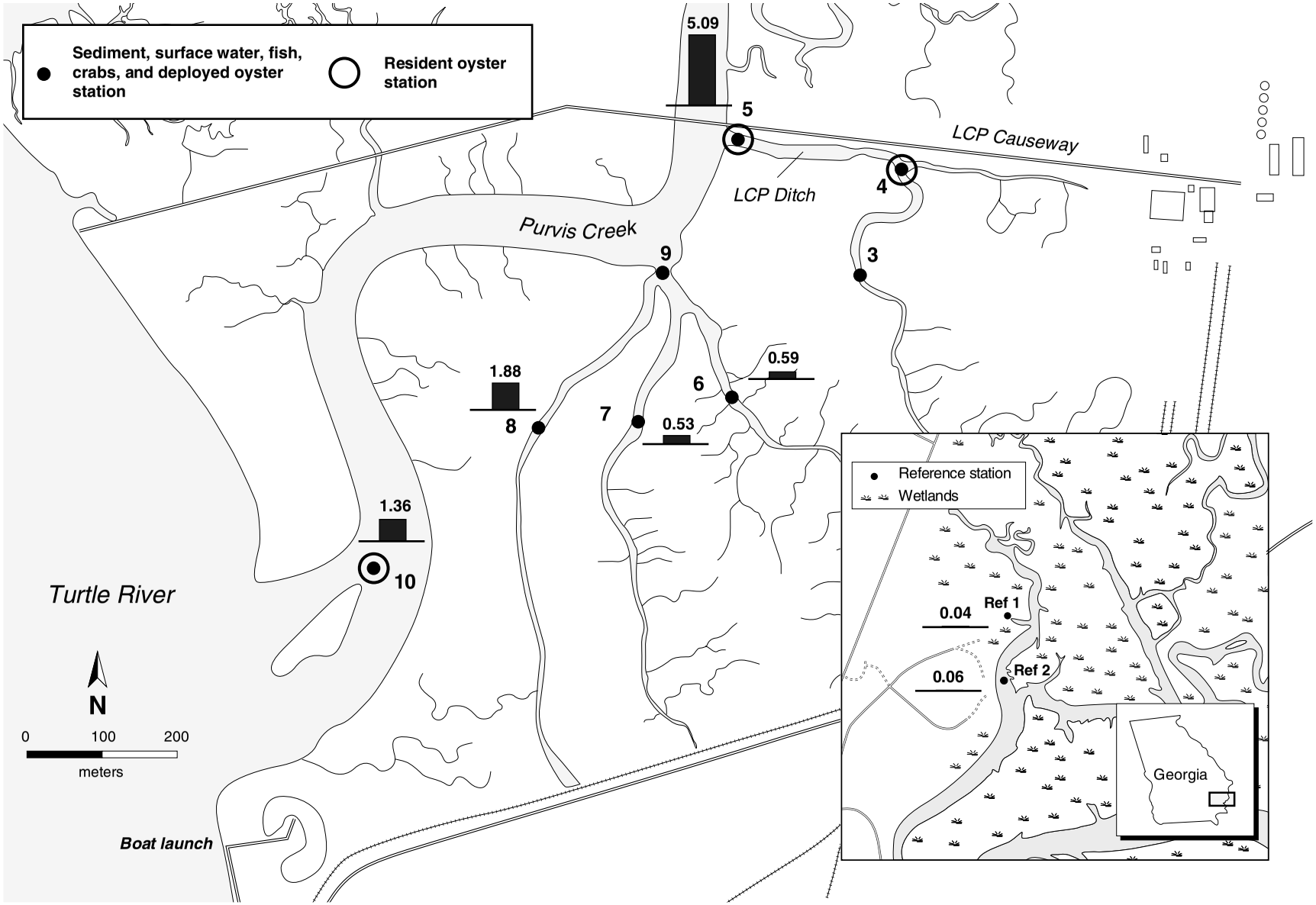


Figure 3.22. Mean Aroclor 1268 in fiddler crab (g/g dry) n=3

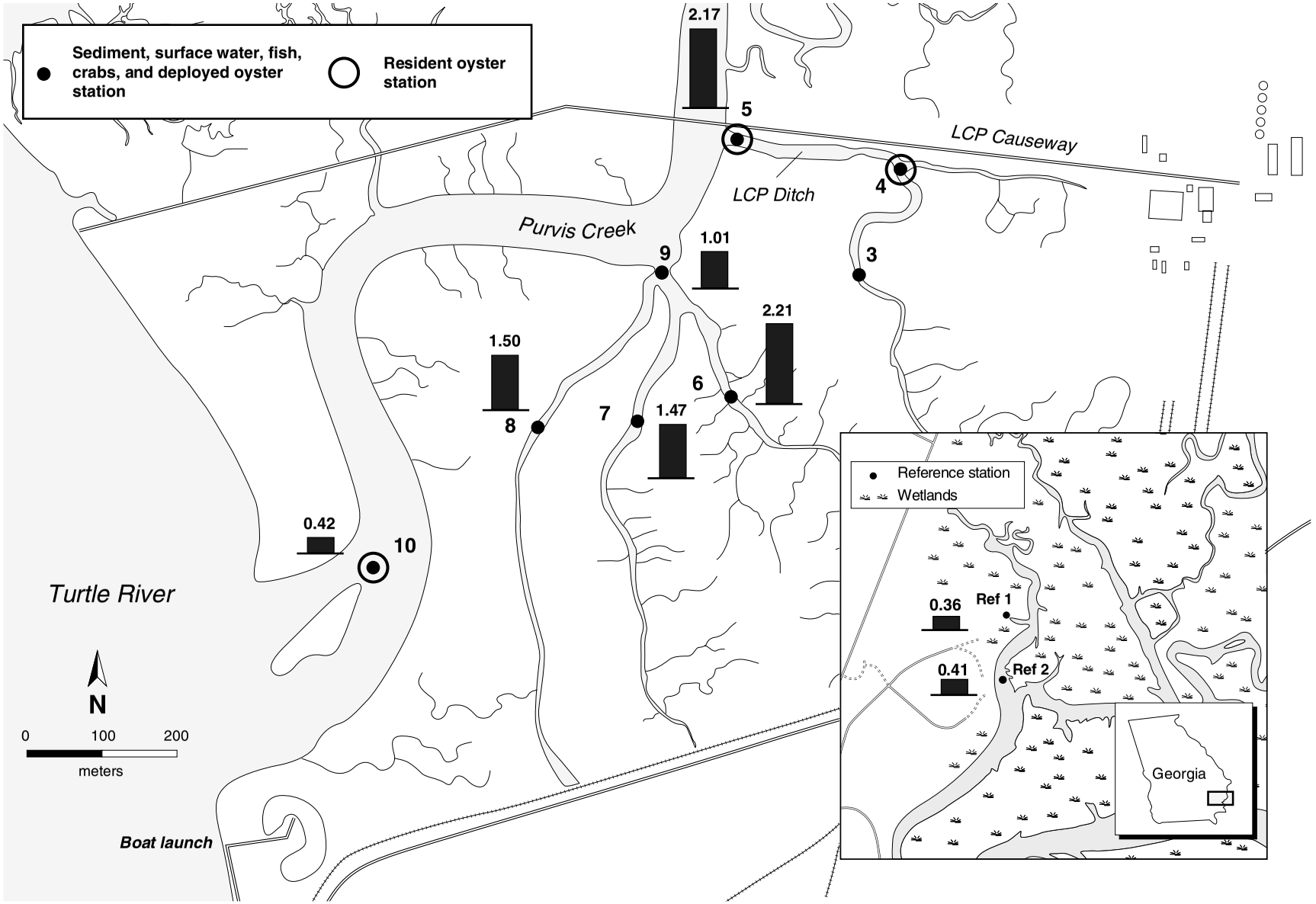


Figure 3.23. Mean lead in fiddler crab (g/kg dry) n=3

Figure 3.24 Total mercury in fiddler crab (µg/g dry weight) with distance from the head of the LCP ditch (station numbers indicated)

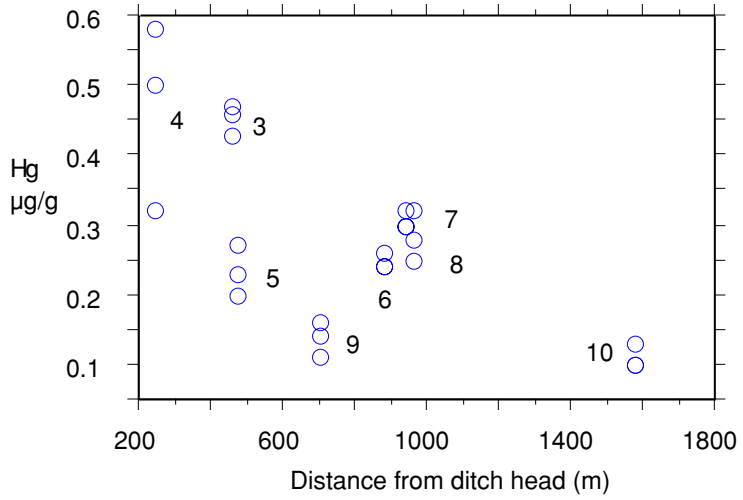
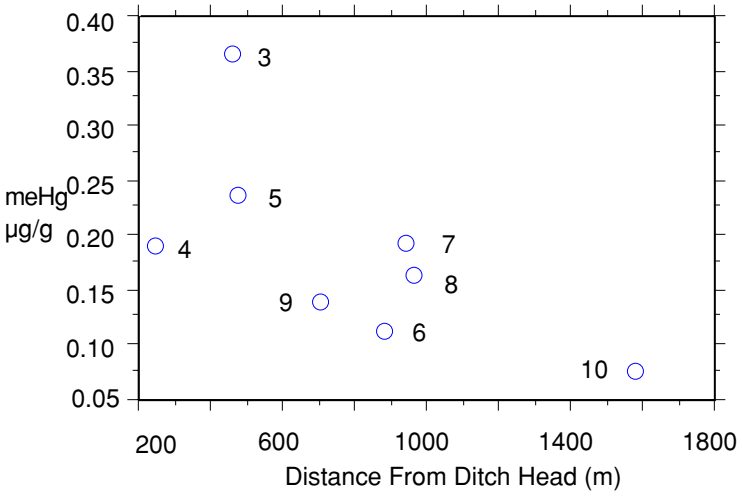


Figure 3.25 Methylmercury in fiddler crab (µg/g dry weight) with distance from the head of the LCP ditch (station numbers indicated)



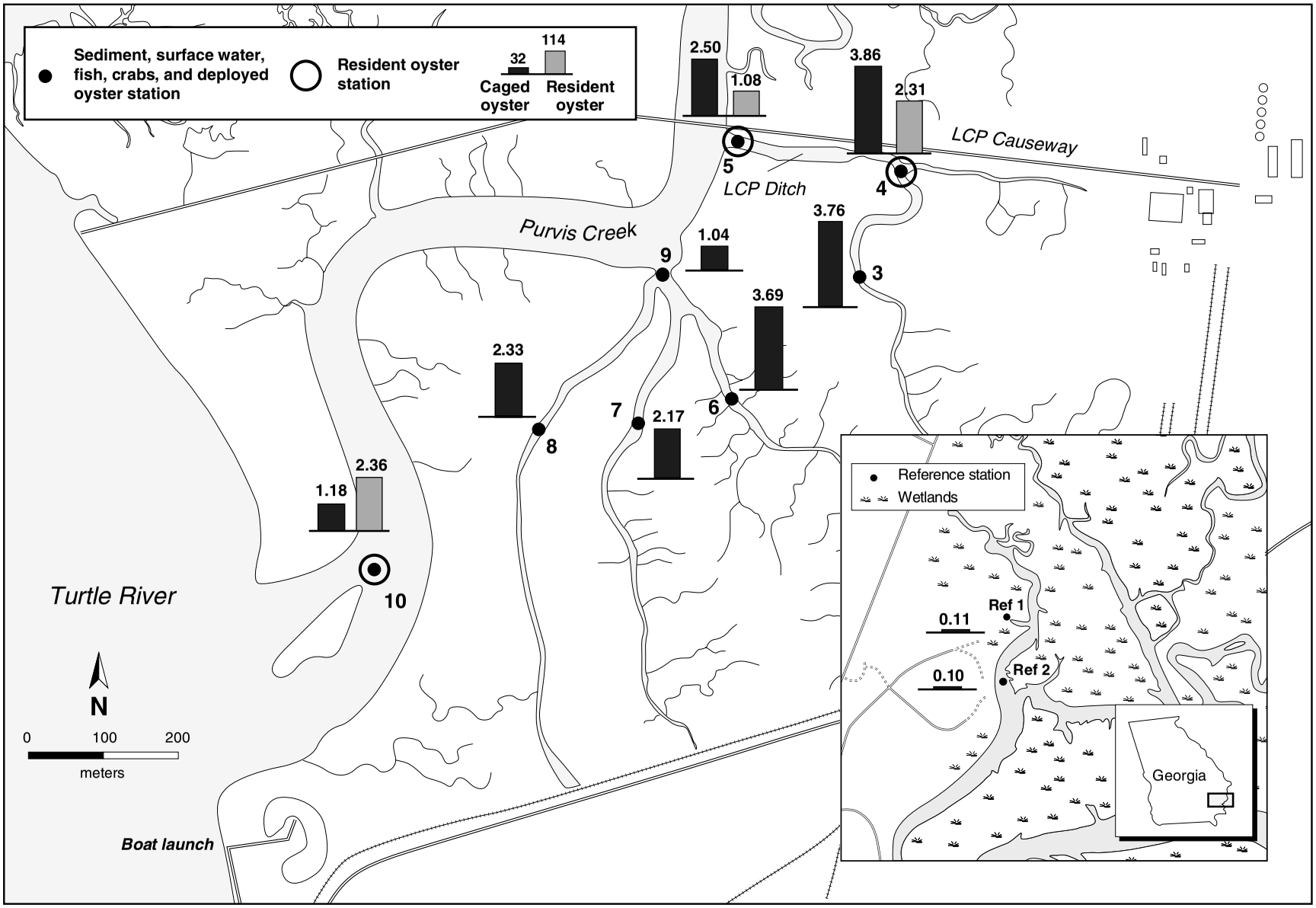


Figure 3.26. Mean total Hg in caged and resident oyster (g/g dry)

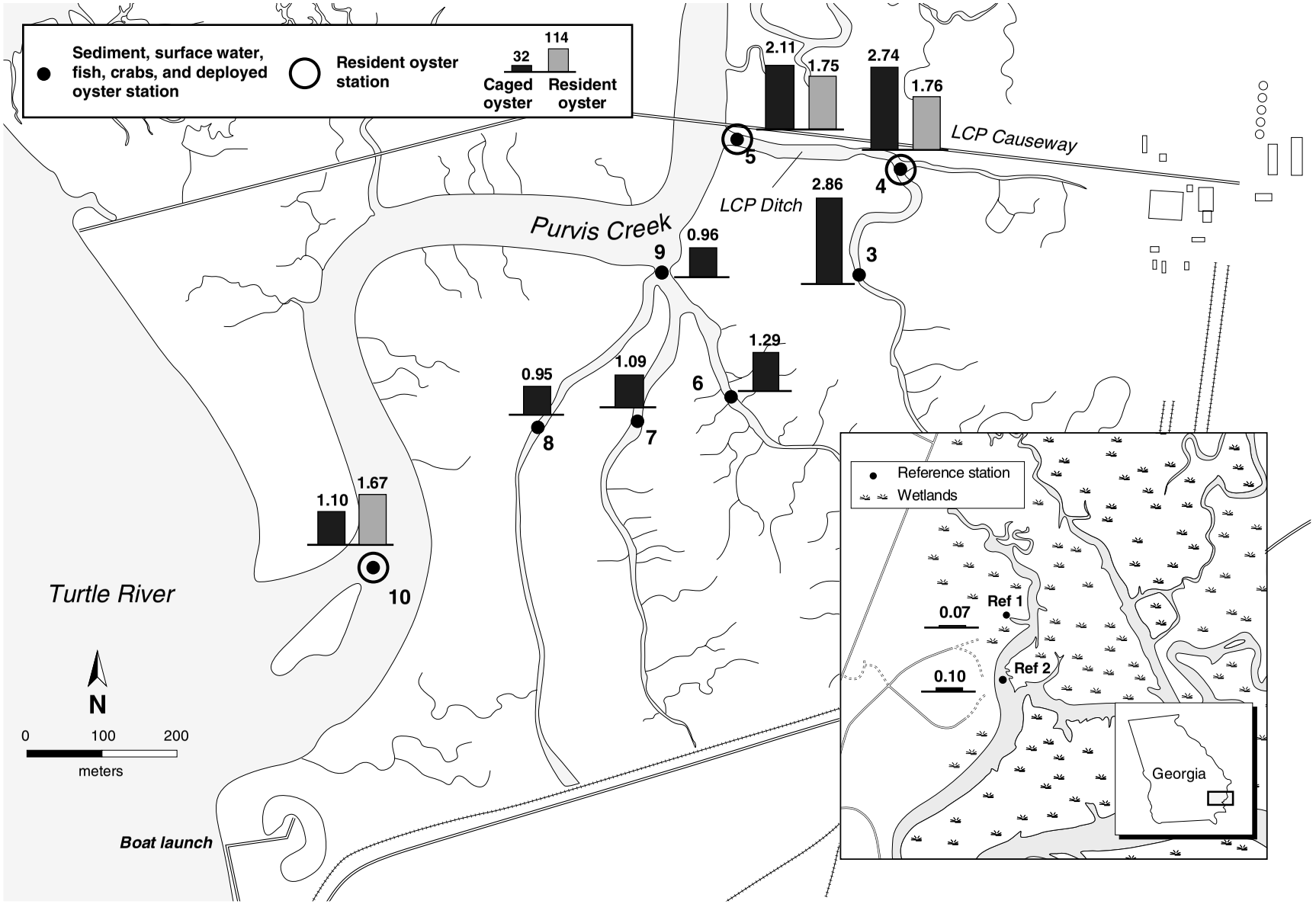


Figure 3.27. Methylmercury in caged and resident oyster (g/g dry)

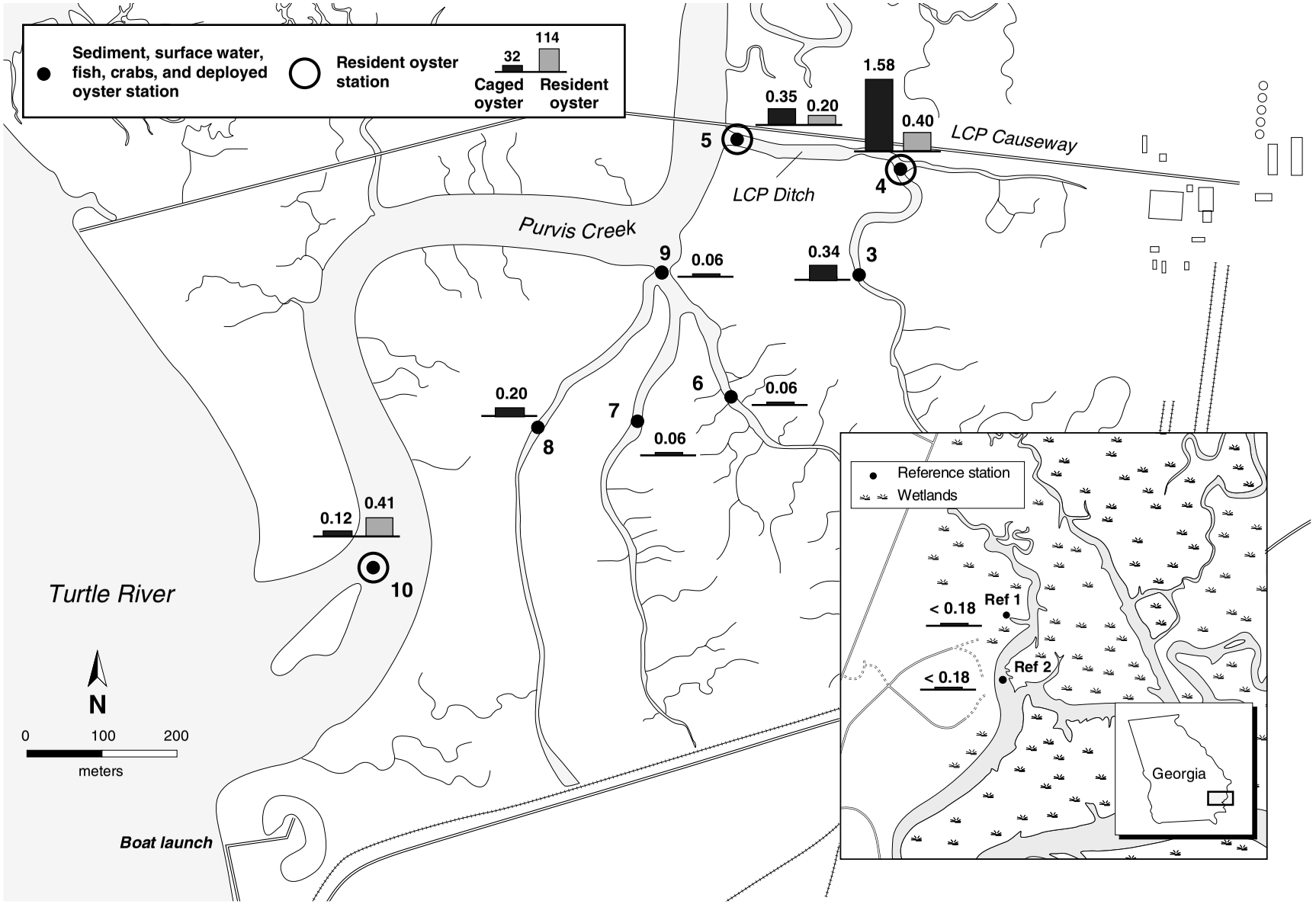


Figure 3.28. Aroclor 1268 in caged and resident oysters (g/g dry)

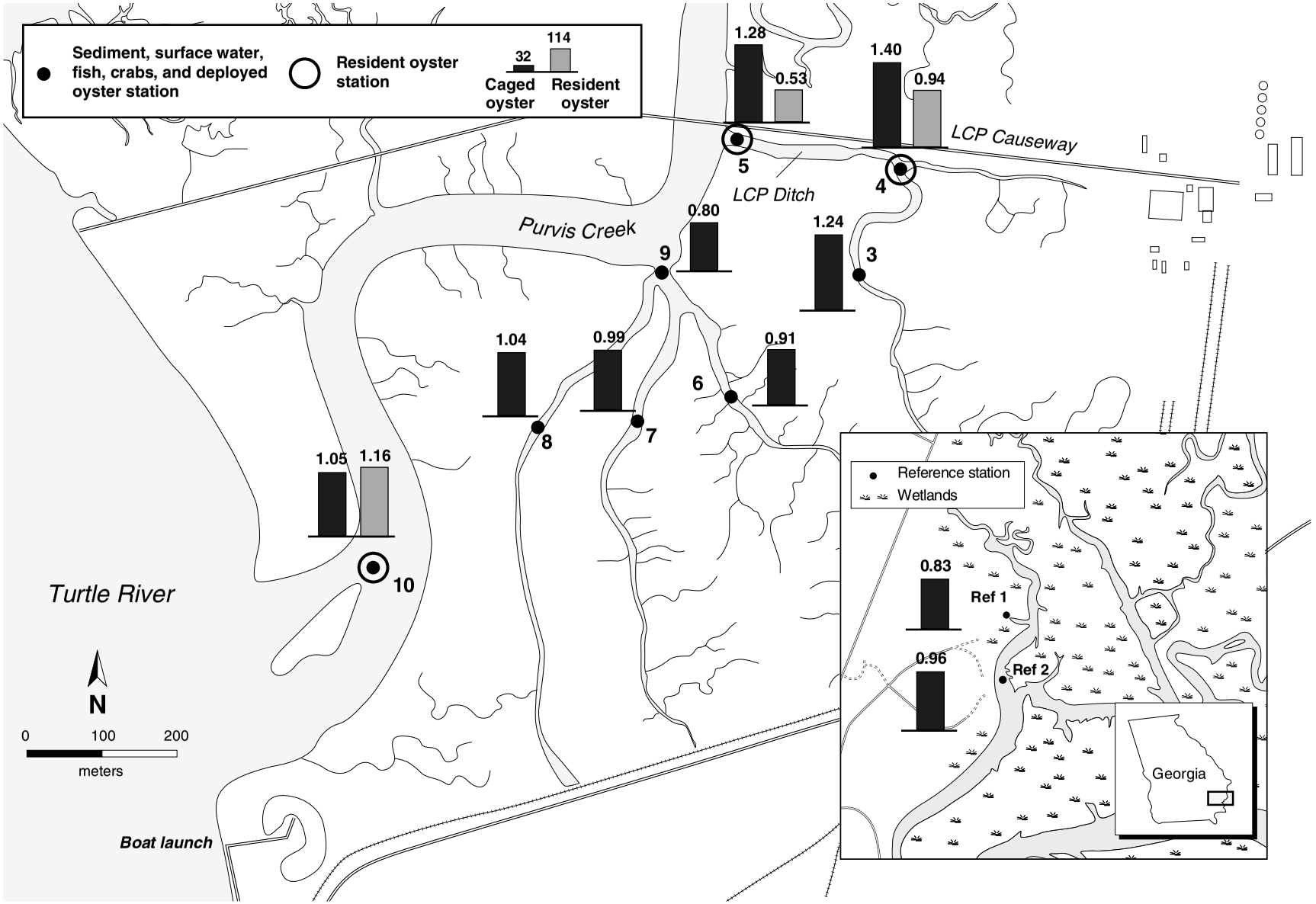


Figure 3.29. Lead in caged and resident oyster (g/g dry)

Figure 3.30 Total mercury content in transplanted oysters (µg/oyster) with distance from the head of the LCP ditch (station numbers indicated)

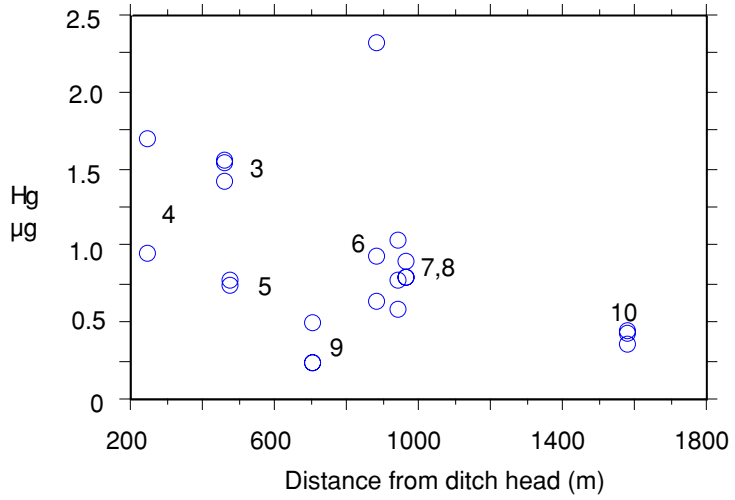


Figure 3.31 Methylmercury content in transplanted oysters (µg/oyster) with distance from the head of the LCP ditch (station numbers indicated)

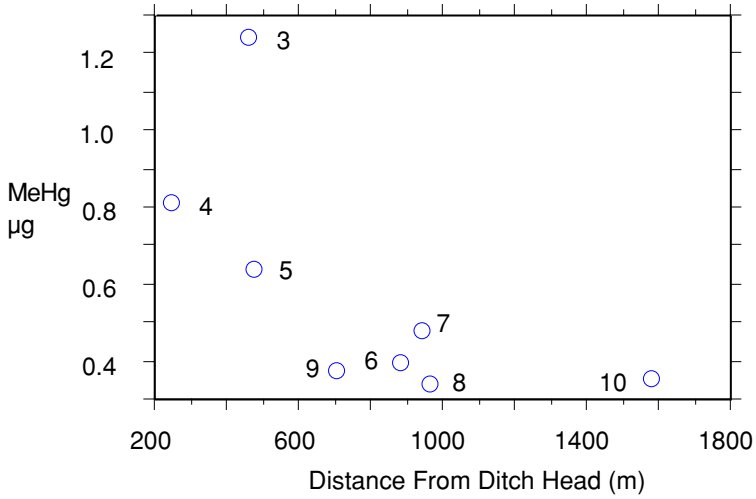
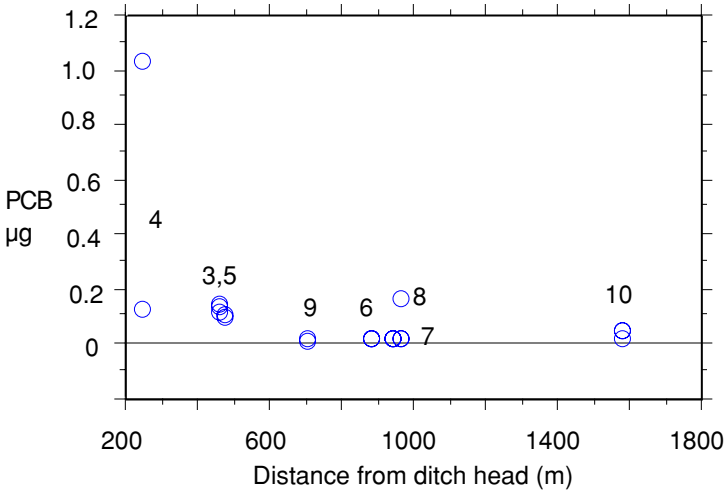


Figure 3.32 Aroclor 1268 content in transplanted oysters (µg/oyster) with distance from the head of the LCP ditch (station numbers indicated)



4.0 Discussion

The quality of data collected in this study was judged to be acceptable for meeting the objectives. Detection limits and the level of replication were adequate to distinguish between concentrations at the site and at reference areas and between stations at the site. Detection limits for PCBs in water were not sufficiently low to determine whether chronic ambient water quality criteria were exceeded.

4.1 Mercury

Mercury concentrations in surface water are highest at stations 3 and 4, especially at low tide. The higher concentrations at low tide seem to indicate that there is an ongoing source of mercury to surface water at the site, which could include releases from previously deposited contaminated sediment. The presence of mercury in both filtered and unfiltered samples indicates that it is not just suspended sediment that is responsible for water contamination. This is also indicated by the fact that although suspended solids concentrations are uniform at the site at high tide, highest mercury concentrations were detected at station 4. At low tide, although suspended solids concentrations were very high at station 5, mercury concentrations in water were higher at station 4. Total mercury in unfiltered water at low tide is higher at stations 6 and 7 than might be expected if the head of the LCP ditch is the only source of mercury to surface water. These observations may indicate that creek sediment may be leaching mercury to surface water.

Chronic AWQCs for mercury are exceeded at all stations at high and low tide.

Total mercury concentrations in bank sediment were highest at stations 3, 4, and 5. Total mercury concentrations in creek sediment were highest at station 4 and 5. Mercury concentrations in sediment at station 3 were variable. A good relationship is found between concentrations in creek sediment and distance from the head of the LCP ditch, suggesting

that this has been a source area for suspended sediment to be transported and deposit on the bottom of the creek beds. For both total and methylmercury, either creek sediment concentrations are higher than bank sediment concentrations (at stations 4, 7, and 8) or there is no difference, suggesting that transport of suspended sediment, and not erosion of bank sediment, may be the most important mechanism for spreading particulate mercury to sediment throughout the site (Appendix A.2). Although statistical comparisons cannot be made between methylmercury concentrations in creek and bank sediment because of the lack of replication, it appears that methylmercury concentrations in bank sediment are always higher than that in creek bottom sediment, and the percentage of methylmercury compared to total mercury is higher in bank sediment than in creek sediment, suggesting that methylation may be occurring at a greater rate on the marsh surface.

Mercury concentrations in fish are highest at stations 3, 4, and 5, showing the same pattern as seen in bank sediments. There is a good relationship betweeen mercury in fish and distance from the head of the ditch. Mercury concentrations in fish correlate with sediment and water concentrations.

The pattern of mercury in fiddler crabs is less distinct than in fish, but stations 3 and 4 have highest concentrations. Mercury in fiddler crabs from station 5 are lower than might be expected given patterns in sediment concentrations. Crab concentrations generally decline away from the head of the ditch, but are higher at stations 6, 7, and 8 than might be expected if the ditch is the only source of mercury to crabs at the site. Crab concentrations correlate with water and sediment concentrations.

The content of total mercury in caged oysters is similar to the pattern seen in bank sediment, with stations 3 and 4 having highest content. Concentrations of total mercury in caged oysters at stations 6, 7, and 8 are higher than would be predicted if the head of the

LCP ditch were the only source of mercury to oysters at the site. Concentrations and content of total mercury correlate with sediment and water concentrations. Methylmercury concentrations in caged oysters correlate significantly only with creek bottom sediment concentrations.

Of the three species sampled for total mercury, caged oysters accumulated higher concentrations than fish and fiddler crabs. Patterns in fish and oysters appeared to match patterns in sediment concentrations better than those in fiddler crabs.

4.2 Aroclor 1268

Aroclor 1268 was only detected in low tide unfiltered water samples at stations 3, 4, 5, and 7. These results indicate that Aroclor 1268 is associated with particulates and that water brought in at high tide dilutes Aroclor 1268 concentrations to below detection limits. Concentrations at stations 3, 4, 5, and 7 exceed ambient water quality criteria at low tide.

Aroclor 1268 concentrations in bank sediment were highest at stations 3, 4, and 5. Creek sediment concentrations were highest at stations 4 and 5. Aroclor 1268 concentrations at station 3 were variable. A good relationship is seen with distance from the ditch head, suggesting that this is a source area for suspended sediment to deposit on the bottom of the creek beds. As with mercury concentrations, either creek sediment concentrations are higher than bank sediment concentrations (stations 4, 7, and 8) or there is no significant difference between them, suggesting that transport of suspended sediment, and not erosion of bank sediment, may be a mechanism for spreading Aroclor 1268 throughout the site (Appendix A.2).

Aroclor 1268 concentrations in fish are highest at stations 3, 4, and 5, showing the same pattern as seen in bank sediments, and the same pattern seen in mercury concentrations.

There is a good relationship betweeen Aroclor 1268 concentrations in fish and distance from the head of the ditch. Aroclor 1268 concentrations in fish correlate with both sediment and water concentrations.

Since Aroclor 1268 was not analyzed in fiddler crabs from stations 3, 4, and 9, distinguishing a pattern is more difficult. Highest concentrations were detected at station 5. Aroclor 1268 concentrations in crabs correlate significantly with concentrations in sediment but not water concentrations.

The content of Aroclor 1268 in caged oysters is similar to the pattern seen in bank sediment, with stations 3, 4 and 5 having highest content. Concentrations and content of Aroclor 1268 correlate with water and sediment concentrations.

Of the three species evaluated in this study, fish accumulated highest concentrations of Aroclor 1268. Oysters accumulated lowest concentrations. Concentrations in fiddler crabs fell in between, although they were not analyzed for Aroclor 1268 at all stations. All three species seemed to track patterns in sediments.

The limited uptake of PCBs by the oysters is surprising. Oysters, as well as many other bivalves, have been shown to be good accumulators of PCBs and other organic contaminants. Limited accumulation may be associated with low lipid concentration, inadequate exposure period, or pathway of exposure. Oysters used in this study had very low lipid concentrations, usually less than 1.5 percent. Lipid concentrations vary during the year depending on location, but can be has high as 8 to 10 percent during the summer months. Local oyster fishermen contacted during the planning stages of this study said that oyster condition in southeastern Georgia was quite poor during the summer months. They called the oysters “bladder oysters” because of their high water content. This condition has

been associated with heavy spawning during the summer months (Amy Ringwood, personal communication, 1997). Although the oysters for this study were cultured in North Carolina, they may have also experienced active spawning before use in this study. It is very likely that the low lipid content of these oysters influences their ability to accumulate PCBs.

4.3 Lead

The source of the elevated lead concentration in surface water (11 µg/L) at high tide at station 2 is not known, but since lead was not detectable at low tide and since sediment concentrations are not elevated at this station, it appears that overall, station 2 was an acceptable reference station for lead concentrations at the site. At the LCP site stations, lead was detected in surface water only at stations 4 and 7 at low tide. Lead concentrations in bank and creek sediment were highest at stations 4 and 5. The pattern of lead contamination at the site is very different from that of mercury and Aroclor 1268.

Lead concentrations in fish do not follow a pattern similar to that seen in sediments, and are not significantly elevated above those found at the reference sites. Concentrations of lead in fish do not correlate with concentrations in sediment or water at the site. Although concentrations in crab were elevated above those at reference sites, there is no correlation between lead in crabs and lead in sediment or water concentrations. The highest lead content in caged oysters was seen at stations 3 and 4, although they were not elevated above those at reference sites. No significant correlations were seen between oyster concentrations and sediment or water concentrations.

Of the three species evaluated in this study, fiddler crabs accumulated highest concentrations of lead. Caged oysters accumulated similar concentrations as fiddler crabs

and fish accumulated lowest concentrations of lead. No patterns in biota were seen that matched patterns in sediment.

5.0 Conclusions and Recommendations

Conclusions of the study are presented by objective.

Objective 1) Examine the bioavailability of mercury, methylmercury, lead, and PCBs in transplanted oysters and in three resident species located near the LCP site relative to uptake at a reference location.

- Mercury and Aroclor 1268 are accumulating in biota at the LCP site in excess of the reference locations. Lead concentrations in fiddler crabs were elevated over those at reference stations.

- Concentrations of mercury and PCBs in biota are correlated to concentrations in both water and sediment, indicating that both water and sediment act as a source pathway to biota.

Objective 2) Provide a characterization in order to assess the success of the upcoming removal action to be taken in the marsh.

- This study provides a basis for later comparisons to determine success of removal and remedial actions at the site.
- Although analysis of surface water often yields highly variable results, in this study, analysis of water sampled at low tide was a useful monitoring tool to indicate potential source areas and determine whether water quality criteria are exceeded.
- Fundulus are useful as monitoring organisms for the site because they accumulated both mercury and Aroclor 1268 in excess of concentrations at the reference sites and are consumed by higher level biota.

- Fiddler crabs are useful as monitoring organisms because they are closely associated with sediments and accumulated both mercury and Aroclor 1268 in excess of those at the reference sites. Fiddler crabs are also consumed by higher level biota.
- Resident oysters may be difficult to monitor in the future because they are not widely distributed over the site and most existing oysters on the site will be destroyed by removal operations. Benefits of using caged oysters include that they do not move, they can be placed in an area of interest where resident oysters are not found, and accumulations in caged oysters represent recently available contamination, and not that accumulated over the lifetime of the resident animal. Disadvantages of caged oysters are that they did not accumulate high concentrations of Aroclor 1268.

Each of the three species used in this study have their advantages. Together, in combination with analysis of water and sediment they provide a more complete picture of bioavailability of contaminants at the site and transfer through the aquatic food chain.

Objective 3) Determine the extent and magnitude of contamination remaining in the marsh after completion of removal actions in the upland portions of the site.

- For many parameters (mercury in sediment, fish, crabs, and oysters and Aroclor 1268 in sediment and fish), there is a good relationship between concentration and distance from the head of the LCP ditch (the location of the former plant outfall), confirming that this has been a major source area for contamination at the site.

- Concentrations of mercury and Aroclor 1268 in water at low tide were higher than those at high tide indicating that mercury is being transported away from the site.

- Creek bottom sediment concentrations of mercury and Aroclor 1268 are higher than or equivalent to those in bank sediments; and the percentage of methyl mercury is higher in bank sediment than in creek bottom sediment, indicating that methylation may be occurring at a greater rate on the marsh surface than in creek bottom sediments.

- This study provides additional information that can be used in the food web model for ecological risk assessment at the site.

6.0 References

Sprenger, M.D., N. J.Finley, and M. Huston. 1997. Final report ecological assessment: ecological risk evaluation of the salt marsh and adjacent areas at the LCP Superfund site, Brunswick, Georgia. April, 1997. EPA.

Appendix A Statistical Comparisons and Correlations

A.1 Statistical Comparisons between Site Stations

A.1.1 Sediment

A.1.1.1 Mercury

10 8 7 9 6 5 4 3

Stations linked by lines are statistically similar in bank total mercury concentration (p<0.000001).

6 9 10 8 7 3 5 4

Stations linked by lines are statistically similar in creek total mercury concentration (p=0.000001).

A.1.1.2 Aroclor 1268

9 8 7 10 6 4 3 5

Stations linked by lines are statistically similar in bank Aroclor 1268 concentration (p<0.000001).

6 9 8 7 10 3 5 4

Stations linked by lines are statistically similar in creek bottom Aroclor 1268 concentration (p=0.000021).

A.1.1.3 Lead

10 9 7 8 6 3 4 5

Stations linked by lines are statistically similar in bank lead concentration (p<0.000001).

3 9 10 7 8 6 4 5

Stations linked by lines are statistically similar in creek bottom lead concentrations (p<0.000001).

A.1.2 Fish

A.1.2.1 Mercury

10 8 6 7 9 5 3 4

Stations linked by lines are statistically similar in fish total mercury concentration (p<0.000001).

A.1.2.2 Aroclor 1268

10 9 8 7 6 5 3 4

Stations linked by lines are statistically similar in fish Aroclor 1268 concentration (p<0.000001).

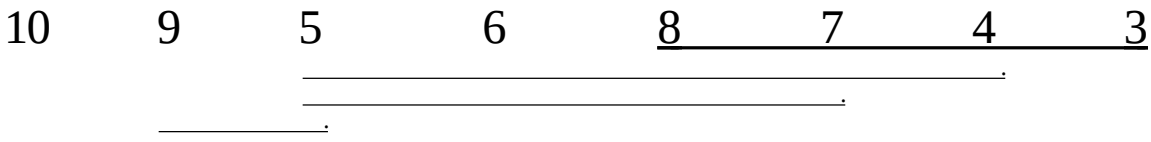
A.1.2.3 Lead

9 10 7 4 6 5 3 8

Stations linked by lines are statistically similar in fish lead concentration (p=0.010).

A.1.3 Fiddler crab

A.1.3.1 Mercury



Stations linked by lines are statistically similar in fiddler crab total mercury concentration (p<0.000001).

A.1.3.2 Aroclor 1268

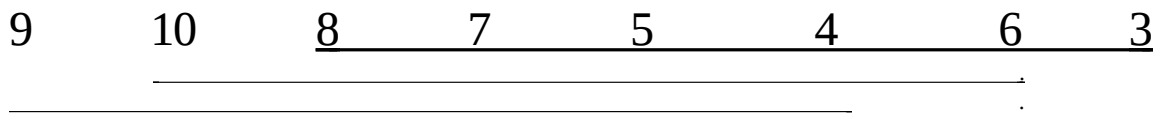
Stations linked by lines are statistically similar in fiddler crab Aroclor 1268 concentration (p<0.000001)

A.1.3.3 Lead

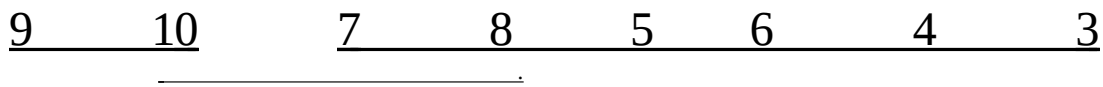
Stations linked by lines are statistically similar in fiddler crab lead concentration (p=0.000009).

A.1.4 Caged oysters

A.1.4.1 Mercury

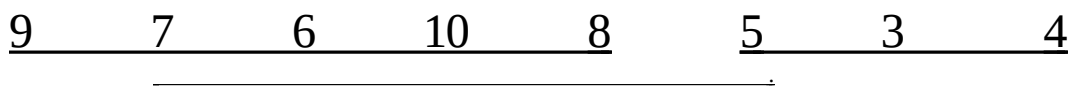


Stations linked by lines are statistically similar in caged oyster total mercury concentration (p=0.0002).

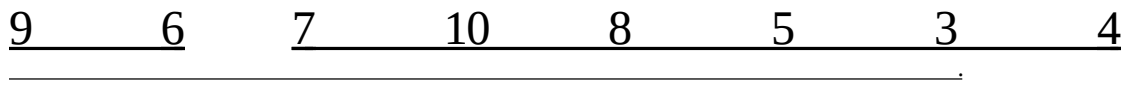


Stations linked by lines are statistically similar in caged oyster total mercury content (p<0.000001).

A.1.4.2 Aroclor 1268

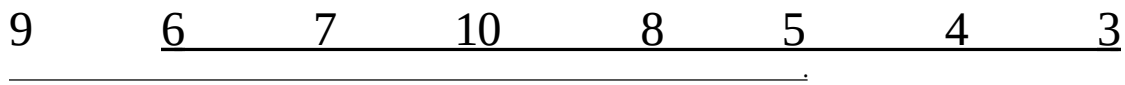


Stations linked by lines are statistically similar in caged oyster Aroclor 1268 concentration (p<0.000001).



Stations linked by lines are statistically similar in caged oyster Aroclor 1268 content (p<0.000001).

A.1.4.3 Lead



Stations linked by lines are statistically similar in lead content.

A.2 Correlations Between Parameters

A.2.1 Sediment

Correlations between total mercury in bank sediment and sulfides, %fines, and total organic carbon were evaluated. Correlations were significant between total mercury and sulfides ($p=0.0007$) and between total mercury and TOC ($p=0.028$). Correlations between methylmercury in bank sediment and sulfides, % fines, and TOC were evaluated. Correlations were signficant between methylmercury and total mercury ($p=0.024$) and methylmercury and % fines ($p=0.023$).

Creek bottom sediment samples were statistically significantly higher in total mercury concentration than bank samples at stations 4, 7, and 8 ($p<0.05$). At station 2, the bank sediment concentration of total mercury was higher than the creek bottom concentration ($p=0.043$). At all other stations, there was no difference between bank and creek bottom sediment mercury concentrations ($p>0.05$). Although statistical comparisons cannot be made between methylmercury concentrations in creek and bank sediment because of the lack of replication, it appears that methylmercury concentrations in bank sediment are always higher than those in creek bottom sediment.

Creek bottom sediment samples were statistically signficantly higher in Aroclor 1268 concentration than bank samples at stations 4, 7, and 8 ($p<0.05$). At all other stations, there was no difference between bank and creek bottom sediment Aroclor 1268 concentrations ($p>0.05$).

A.2.2. Fish

Spearman rank order correlations were examined to compare fish concentrations to those in low tide filtered water, bank sediment, and creek bottom sediment. For total mercury, correlations were significant between fish concentrations and water concentrations

(p=0.0032); fish concentrations and bank sediment concentrations (p<0.000001); and fish concentrations and creek sediment concentrations (p<0.000001). For methylmercury, correlations were examined between fish concentrations and bank or creek bottom sediment. Correlations were significant between fish and both sediment types (p=0.037 for bank sediment and p=0.00086 for creek bottom sediment).

For Aroclor 1268 concentrations, correlations were significant between fish concentrations and water concentrations (p=0.0053); fish and bank sediment concentrations (p<0.000001); and fish and creek sediment concentrations (p=0.00002).

There were no significant correlations between lead concentrations in fish and water or sediment lead concentrations.

A.2.3 Crabs

Spearman rank order correlations were examined to compare fiddler crab concentrations to those in low tide unfiltered water, bank sediment, and creek sediment. For total mercury, correlations were signficant between crab concentrations and water concentrations (p=0.00013); crab and bank sediment concentrations (p=0.000033); and crab and creek sediment concentrations (p=0.000054). For methylmercury, correlations were not significant between fiddler crabs and bank or creek bottom sediment (p>0.10).

For Aroclor 1268 concentrations, correlations were significant between crab concentrations and bank sediment concentrations (p=0.00056); and between crab and creek sediment concentrations (p=0.00004).

For lead concentrations in fiddler crab, there were no significant correlations with water or sediment lead concentrations.

A.2.4 Resident Oysters

Spearman rank order correlations were examined to compare concentrations of total mercury, Aroclor 1268, and lead in resident oysters to those in low tide filtered water, bank sediment, and creek sediment. None of the correlations were significant ($p>0.07$).

A.2.5 Caged oysters

Spearman rank order correlations were examined to compare caged oyster concentrations to those in low tide unfiltered water, bank sediment, and creek sediment. For total mercury concentrations, correlations were significant between oyster concentrations and bank sediment concentrations ($p<0.00001$); oysters and creek sediment concentrations ($p=0.00009$); and oysters and low tide unfiltered water concentrations ($p=0.00237$). For methylmercury, correlations were significant only between oyster concentrations and creek sediment concentrations ($p=0.024$).

Correlations were significant between Aroclor 1268 oyster concentrations and bank sediment concentrations ($p=0.00065$); between oysters and creek sediment concentrations ($p=0.00039$); and between oysters and low tide unfiltered water concentrations ($p=0.014$).

No significant correlations were found between lead concentrations in caged oysters and those in water or sediment.

Appendix B Ancillary Parameters- Transplanted Oysters

Two metrics were used to assess growth for the purposes of calculating contaminant uptake in terms of content: whole-animal wet-weight and end-of-test tissue weight. Only whole-animal wet-weight was measured for each individual at the start of the test. Therefore, the change (i.e., increase or decrease) could only be determined for this metric. Because of the closeness in size distribution among stations at the start of the test, it was assumed that the average tissue weight was also similar among stations. Based on this assumption, the end-of-test tissue weights were evaluated for statistical differences; any differences observed were assumed to have occurred during the test period.

B.1 Survival

Survival was variable across the stations with averages ranging from 47 to 98 percent (Figure B-1; Table B-1). Survival among replicates varied from 0 to 100 percent. Two cages, one at Station 4 and the other at Station 5, contained no living animals when they were retrieved, though the other two cages at each of these stations had moderately high survival rates (84 to 94 percent and 70 to 72 percent, respectively). It is possible that silt could have covered these cages, preventing the cages from rising and falling with the tide. Excessive silt may have smothered the oysters in these cages.

The survival data were analyzed for differences among stations using a contingency table. Based on this, the null hypothesis of equal survival rates among all stations was rejected. Using a series of 1x2 contingency tables partitioned from the entire data set, the mean percentage survival at Stations 4, 5 and 9 was found to be significantly lower than the expected survival rate based on the mean of the reference stations. This analysis also indicated that survival at Stations 3, 7, and 8 was significantly higher than at the reference stations (Figure B-1).

B.2 Whole-Animal Wet-Weight

At the start of the test, actual whole-animal wet-weight for individual oysters ranged from 11.9 to 46.2 g. The mean whole-animal wet-weight at each station was about 22.5 g (Table B-2). Whole-animal wet-weight increased at all stations during the 62-day exposure. Mean end-of-test (EOT) whole-animal weights by station ranged from 24.6 to 30.0 g (Figure B-2; Table B-2); the overall range for individuals was from 14.7 to 52.6 g. The greatest EOT weights were measured for oysters at both reference stations; oysters at test Station 9 also had large EOT wet-weights. The lowest EOT weights were measured for oysters at Station 5. Dunnett's multiple comparison test indicated a significant increase in whole-animal wet-weight at all stations when compared to the initial wet-weights.

The EOT whole-animal wet-weight data were normal and suitable for parametric analyses. The results of the ANOVA indicated significant differences between stations ($p < 0.00001$); the Bonferroni test indicated that EOT whole-animal wet-weights were significantly lower at all site stations except Station 9 when compared to the two reference stations. The site stations were compared to each other with the Newman-Keuls test. Results of this analysis indicated that EOT whole-animal wet-weights for oysters at Station 9 were significantly greater than at Stations 4, 5, 6, and 8 (Figure B-2; Table B-2).

Calculated growth rates by station based on changes in whole-animal wet-weight ranged from 296 to 938 mg/wk (FigureB-3; Table B-2). The greatest growth rates were measured for oysters at both reference stations with oysters at Station 2 having the highest measured growth rates. Oysters at test Station 9 also had large growth rates, but they were less than those at the reference areas. The lowest EOT weights were measured for oysters at Station 6. The data presented in Table B-2 shows negative growth rates encountered at all stations. It is very likely that exposure conditions, particularly temperature, were at the limit for these oysters and caused some individuals to lose tissue weight.

The growth rate data were not normal and required a rankit transformation before conducting the parametric analyses. The results of the ANOVA indicated significant differences between stations ($p < 0.00001$); the Bonferroni test indicated that growth rates were significantly lower at all site stations when compared to the two reference stations. The site stations were compared to each other with the Newman-Keuls test. Results of this analysis indicated the following relationships in growth rates among the site stations:

6 8 4 5 7 3 10 9

Stations linked by lines are statistically similar in oyster growth rate

B.3 End-of-Test Tissue Weights

Mean tissue weight at the start of the test by station was estimated at 2.20 g-wet. This estimate was based on the tissue weights measured for the 150 animals used for time zero, test initiation (T_0) tissue chemistry analyses (Table B-2). Mean EOT tissue weights by station ranged from 2.15 to 3.20 g, the overall range for individuals was 0.60 to 7.17 g (Figure B-4; Table B-2). The largest tissues were measured in oysters deployed at both reference stations. Oysters at Stations 4 and 8 had the largest tissues among site oysters. The average tissue weight at all stations except Station 5 in the LCP Ditch were higher than the average tissue weight for T_0 oysters. This suggests that oysters at all stations except station 5 grew during the test period.

The EOT tissue data were suitable for parametric analyses without transformation. The results of the ANOVA indicated significant differences between stations ($p < 0.00001$); the Bonferroni test indicated that EOT tissue weights were significantly lower at all site stations when compared to the two reference stations (Table B-3). The site stations were compared to each other with the Newman-Keuls test. Results of this analysis indicated that Station 5

was significantly lower than Stations 3, 4 and 8. EOT tissue weights were similar among all other site stations.

B.4 Percent Lipids

Mean lipid concentration at the start of the test by station was estimated at 1.00 percent. This estimate was based on the lipid concentration measured for the 150 animals used for time zero, test initiation (T_0) tissue chemistry analyses (Table B-2). Mean EOT lipid concentrations by station ranged from 0.27 to 1.38 percent, the overall range for individuals was 0.00 to 1.53 percent (Figure B-5; Table B-2). The highest lipid concentrations were measured in oysters deployed at both reference stations; oysters at Stations 3 and 7 had the highest lipid concentrations among site oysters. The average lipid concentration at many of the site stations after the 62-day deployment was lower than estimated at the start of the test.

The percent lipid data were suitable for parametric analyses without transformation. The results of the ANOVA indicated significant differences between stations ($p < 0.0024$); the Bonferroni test indicated that percent lipids were significantly lower at Stations 4, 5, 6, 8 and 9 when compared to the two reference stations (Table B-3). The site stations were compared to each other with the Newman-Keuls test. Results of this analysis indicated that lipid concentration at Station 4 was significantly lower than at all other site stations.

B.5 Percent Water

The percentage of water in the soft tissues is related to animal health, with healthier individuals having less water. Mean water concentration at the start of the test by station was estimated at 82.1 percent. This estimate was based on the water concentration measured for the 150 animals used for time zero, test initiation (T_0) tissue chemistry analyses (Table B-2). Mean EOT water concentrations by station ranged from 81.9 to 86.1

percent, the overall range for individuals was 81.2 to 86.4 percent (Figure B-6; Table B-2). The lowest water concentrations were measured in oysters deployed at both reference stations; oysters at Station 3 had the lowest water concentrations among site oysters. The percent water data were suitable for parametric analyses without transformation. The results of the ANOVA indicated significant differences between stations (p = 000061); the Bonferroni test indicated that percent water was significantly higher at all site stations when compared to the two reference stations (Table B-3). The site stations were compared to each other with the Newman-Keuls test. Results of this analysis indicated no differences in percent water among site stations.

B.6 Temperature

Prior to testing the two hypotheses for temperature, temperature profiles were made for each station using the entire set of data collected during the deployment period (Figure B-7). These profiles show that there was a high degree of temperature fluctuation at each station over the test period with temperatures at Station 8 fluctuating the most. In fact, the temperatures at Station 8 frequently exceeded 37^{o}C, the limit of the recording devices. At each station, the measured fluctuations coincide with tidal position.

B.6.1 Differences in Average Daily Temperatures

The results of the paired t-tests (Table 3.16) indicate that the mean daily temperature for Reference Station 1 was significantly colder than all other stations. The mean daily temperature for Reference Station 2 was significantly colder than Stations 5, 9, and 10. Figure B-8 provides graphs of average daily temperatures by station.

B.6.2 Weekly Temperature Ranges

The results of the ANOVA indicated that there is a significant difference between the average weekly temperature ranges at all stations. The results of Newman-Keuls Multiple Range test indicated the weekly range of temperatures at reference station 1 differs significantly from all study sites except 3 and 7. Reference station 2 has a significantly lower weekly range than sites 7 and 8. The average of the weekly temperature ranges are provided in Table B-5.

Table B-1. End-of-test percent survival for oysters

	Station									
	1-Ref	2-Ref	3	4	5	6	7	8	9	10
Replicate 1	88	68	96	84	0	88	72	94	88	46
Replicate 2	36	80	100	0	70	74	98	80	36	78
Replicate 3	98	98	98	94	72	86	96	76	16	94
Mean	74	82	98	59	47	83	89	83	47	73
Standard Deviation	33	15	2	52	41	8	14	9	37	24
Total number surviving	111	122	147	81	71	122	133	124	70	109

Table B-2 LCP Oyster Study: Descriptive statistics for growth metrics

			Station									
		Initial	**1-Ref**	**2-Ref**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Initial	Mean	20.5	22.5	22.0	22.6	22.9	22.3	22.4	22.5	22.5	22.5	22.6
WAWW	Min.	15.4	13.6	15.0	15.1	15.0	14.3	15.2	11.9	14.8	13.3	15.5
(g)	Max.	34.1	37.2	42.7	34.2	38.2	34.8	36.5	36.4	46.2	39.7	42.2
	Std. Dev	3.88	4.93	4.57	4.90	5.17	5.17	4.27	4.74	5.41	5.08	4.88
	N	150	150	150	150	150	150	150	150	150	150	150
End-of-Test	Mean		29.0	30.0	26.4	25.2	24.6	25.1	26.3	25.2	28.1	26.7
WAWW	Min.		16.0	16.3	15.0	15.3	14.8	15.2	14.7	16.4	15.8	16.2
(g)	Max.		51.1	47.8	15.0	42.5	37.1	38.6	45.6	52.6	51.1	47.9
	Std. Dev		6.64	6.90	5.30	4.85	5.39	4.69	5.57	5.81	6.82	5.78
	N		111	123	147	81	71	121	133	123	70	109
Difference WAWW	Mean		6.16	8.31	3.77	2.62	2.90	2.33	3.69	2.51	5.45	4.53
(g)	Min.		-4.72	-1.50	-3.54	-7.09	-2.25	-2.94	-1.52	-0.41	-1.07	-1.67
	Max.		23.0	24.0	15.4	9.3	13.2	7.1	14.6	12.8	15.5	16.3
	Std. Dev		4.93	5.14	2.94	3.13	2.91	2.00	2.48	1.96	3.26	3.47
	N		111	123	147	81	71	121	133	123	70	109
WAWW	Mean		695	938	425	296	328	263	417	284	615	511
Growth Rate	Min.		-533	-169	-400	-800	-254	-332	-172	-46	-121	-188
(mg/wk)	Max.		2593	2709	1740	1051	1493	802	1643	1441	1751	1840
	Std. Dev		557	580	332	353	328	226	280	221	368	392
	N		111	123	147	81	71	121	133	123	70	109
End-of-Test	Mean	2.20	3.20	3.15	2.51	2.50	2.15	2.24	2.29	2.52	2.41	2.29
Tissue	Min.	0.81	1.01	0.60	1.14	1.01	0.97	0.85	0.89	1.07	1.11	0.64
(g)	Max.	4.76	7.17	6.49	4.94	5.56	3.86	4.87	4.49	5.11	4.36	4.12
	Std. Dev	0.67	0.94	1.02	0.66	0.79	0.68	0.68	0.65	0.78	0.73	0.67
	N	148	111	123	146	81	71	121	133	123	70	109
Percent	Mean	1.00	1.38	1.26	1.12	0.27	0.57	0.94	1.15	0.94	0.59	1.08
Lipids	Min.	1.00	1.14	1.06	1.03	0	0	0.85	1.04	0.84	0	0.9
	Max.	1.00	1.53	1.4	1.22	0.82	0.87	1.04	1.29	1	0.98	1.23
	Std. Dev	0.00	0.21	0.18	0.10	0.47	0.49	0.10	0.13	0.09	0.52	0.17
	N	3	3	3	3	3	3	3	3	3	3	3
Percent	Mean	82.1	81.9	82.1	83.9	86.1	85.8	84.8	84.2	85.9	85.9	84.2
Moisture	Min.	81	81.4	81.2	82.8	86	85.6	83.3	83.8	85.1	85.3	83.7
	Max.	82.8	82.4	83.6	85	86.2	86	86.3	84.4	86.4	86.5	84.9
	Std. Dev	0.96	0.50	1.31	1.10	0.14	0.28	1.50	0.32	0.68	0.60	0.61
	N	3	3	3	3	2	2	3	3	3	3	3

Table B-3. Results of statistical analyses comparing growth metrics and survival of average Reference Stations to each other station.

Treatment station means significantly lower than average of Reference Stations 1 and 2:

VARIABLE	3	4	5	6	7	8	9	10
Survival	NS[a]	*	*	NS	NS[a]	NS[a]	*	NS
WAWW	*	*	*	*	*	*	NS	*
WAWW Growth Rate	*	*	*	*	*	*	*	*
EOT Tissue Weight	*	*	*	*	*	*	*	*
% Moisture	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
% Lipids	NS	*	*	*	NS	*	*	NS

NOTE: NS - Not significant

NS[a] - Significantly greater than mean of Reference Stations.

Table B-4. LCP temperature comparisons across stations

Null hypothesis: The average daily temperature is the same.					
Alternative: There is a difference in average daily temperature					
Stations	**Mean difference**	**Std Dev**	**t-statistic**	**df**	**p-value**
Station 1 - Station 2	-0.616	0.116	-5.309	**20**	*0.0000*
Station 1 - Station 3	-0.643	0.144	-4.469	20	*0.0002*
Station 1 - Station 4	-0.571	0.181	-3.152	20	*0.0050*
Station 1 - Station 5	-0.876	0.162	-5.425	20	*0.0000*
Station 1 - Station 6	-0.502	0.143	-3.527	20	*0.0021*
Station 1 - Station 7	-0.616	0.145	-4.263	20	*0.0004*
Station 1 - Station 8	-0.615	0.137	-4.489	20	*0.0002*
Station 1 - Station 9	-0.926	0.189	-4.911	20	*0.0001*
Station 1 - Station 10	-0.859	0.182	-4.733	20	*0.0001*
Station 2 - Station 3	-0.081	0.057	-1.423	20	0.1701
Station 2 - Station 4	0.045	0.102	0.445	20	0.6614
Station 2 - Station 5	-0.318	0.105	-3.017	20	*0.0068*
Station 2 - Station 6	0.039	0.073	0.540	20	0.5951
Station 2 - Station 7	-0.012	0.089	-0.131	20	0.8969
Station 2 - Station 8	0.001	0.141	0.007	20	0.9944
Station 2 - Station 9	-0.338	0.120	-2.809	20	*0.0108*
Station 2 - Station 10	-0.243	0.112	-2.180	20	*0.0414*

Table B-5. Average weekly temperatures by station.

Station:	1	2	3	4	5	6	7	8	9	10
Mean	12.89	9.02	10.63	7.28	8.73	9.42	14.69	18.96	6.79	6.77

Figure B-1. Percent Survival of Oysters

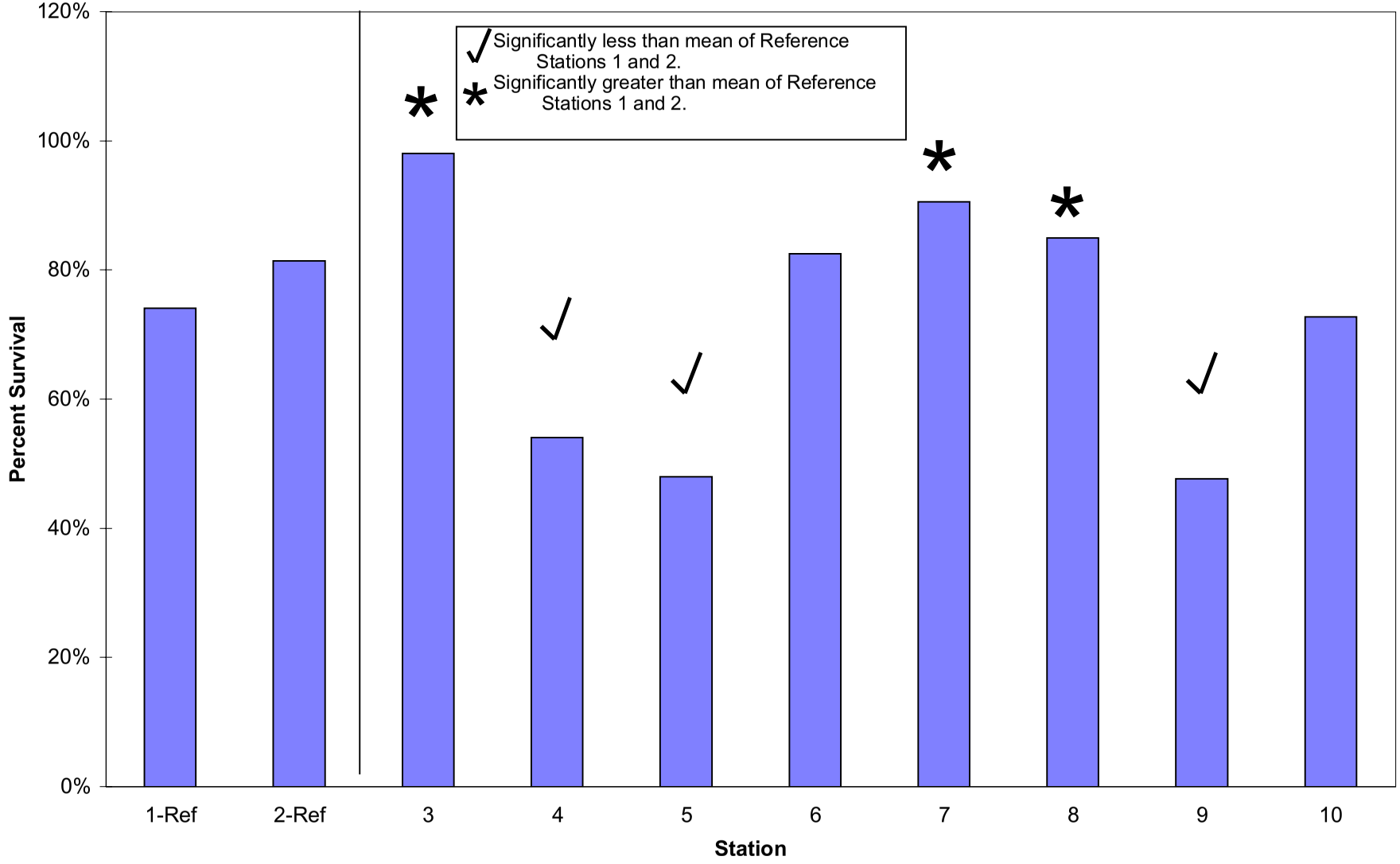


Figure B-2. End-of-Test Whole-Animal Wet-Weight

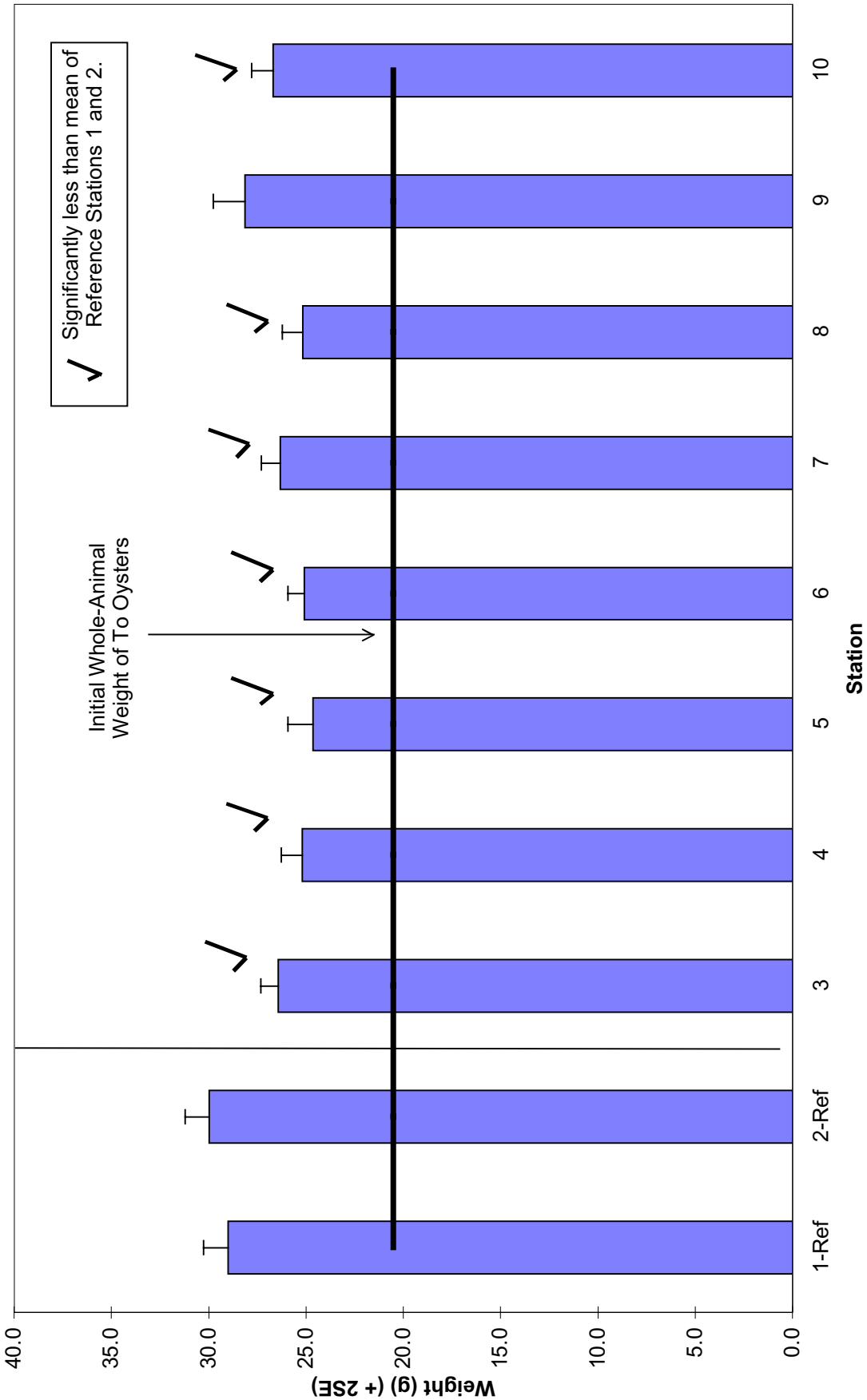


Figure B-3. Oyster Growth during Deployment Period

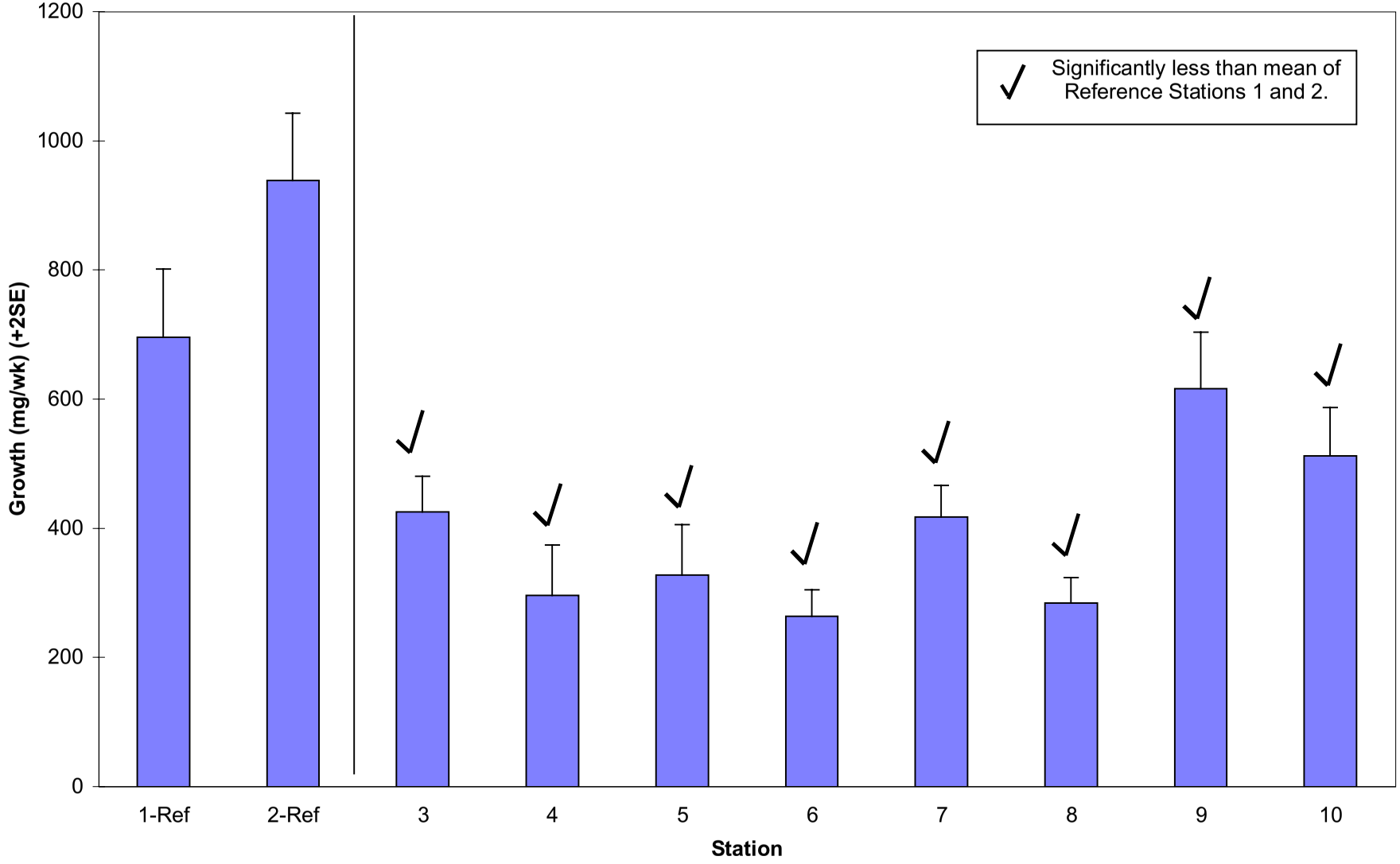


Figure B-4. End-of-Test Oyster Tissue Weights

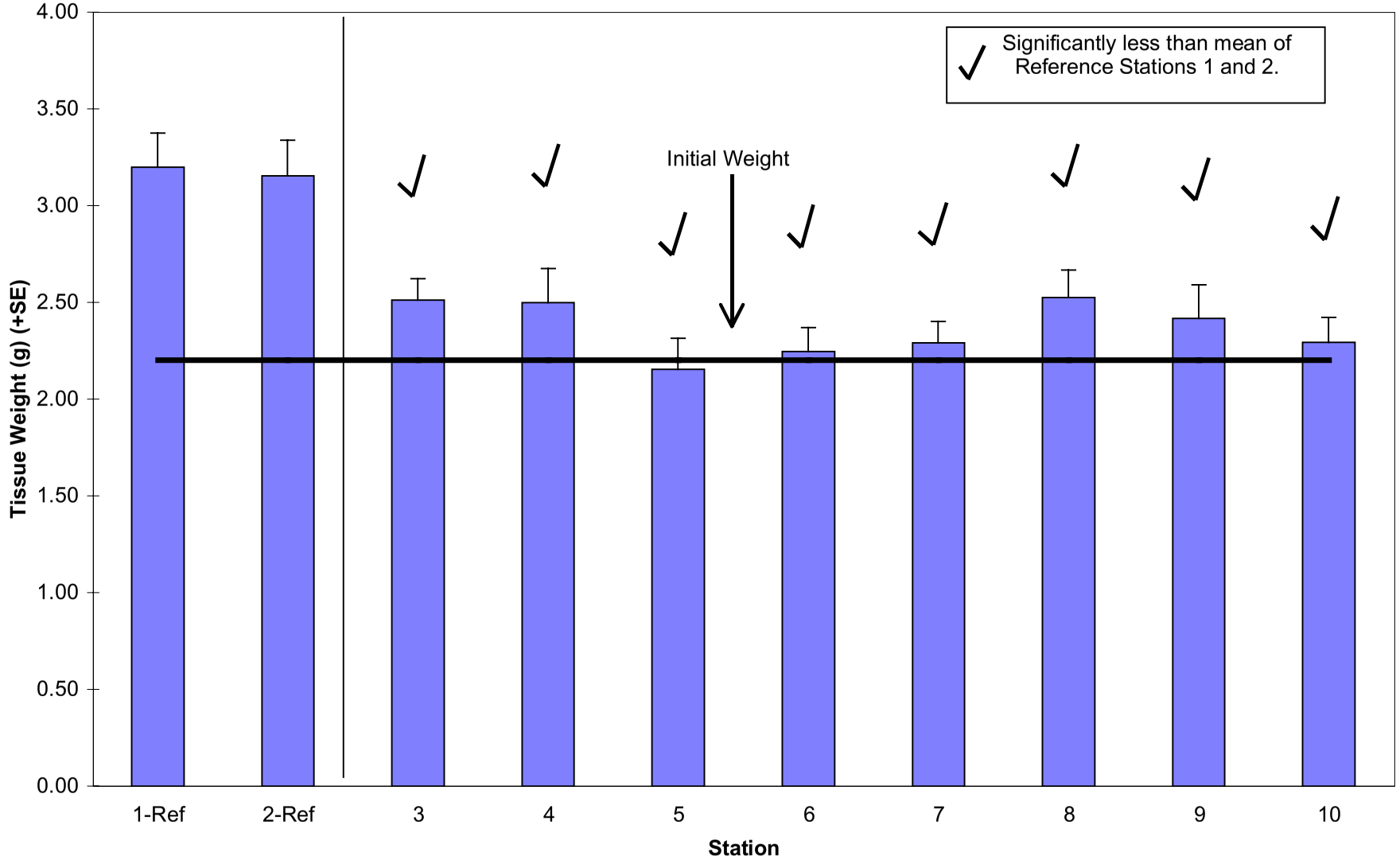


Figure B-5. End-of-Test Percent Lipids in Caged Oysters

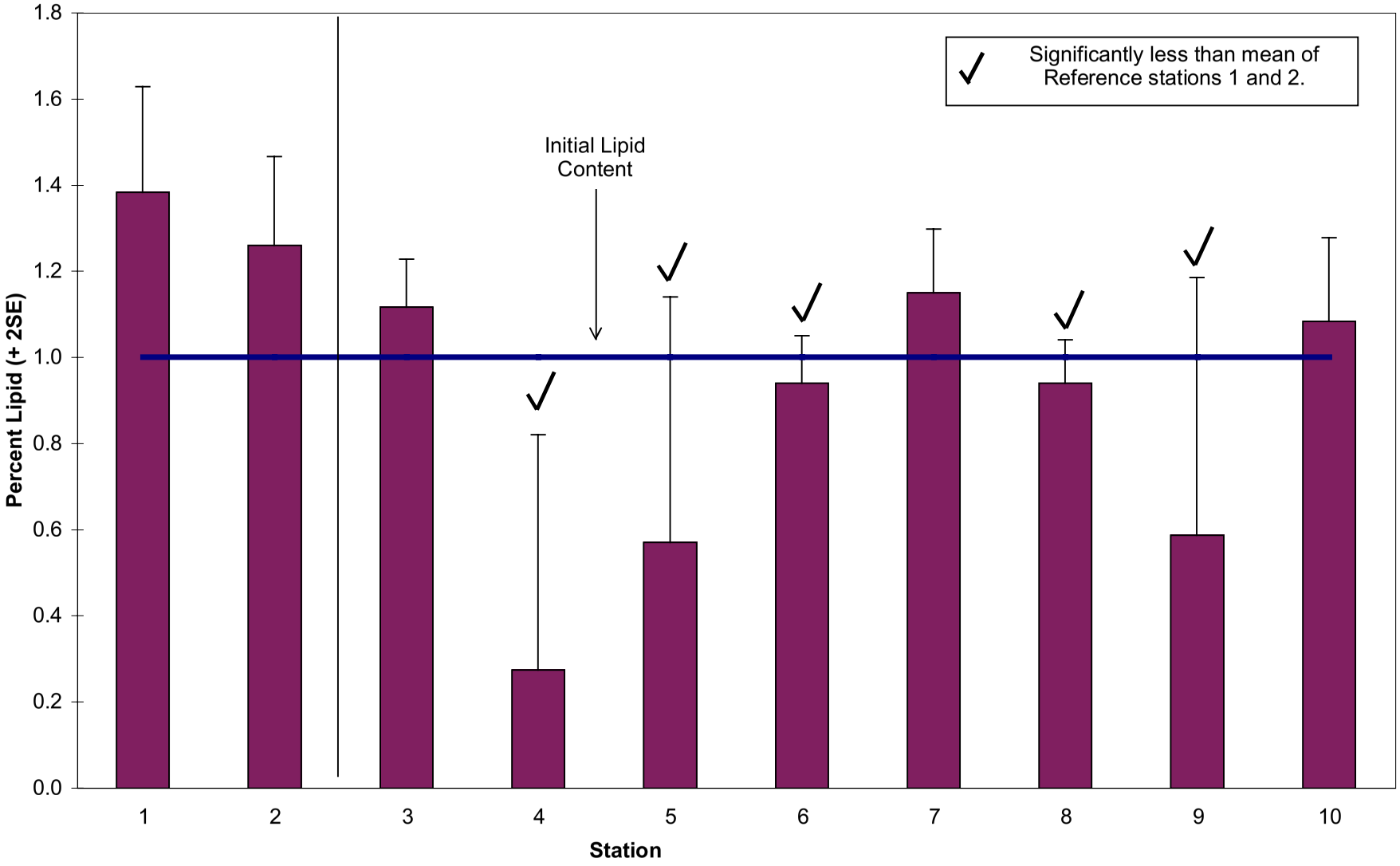
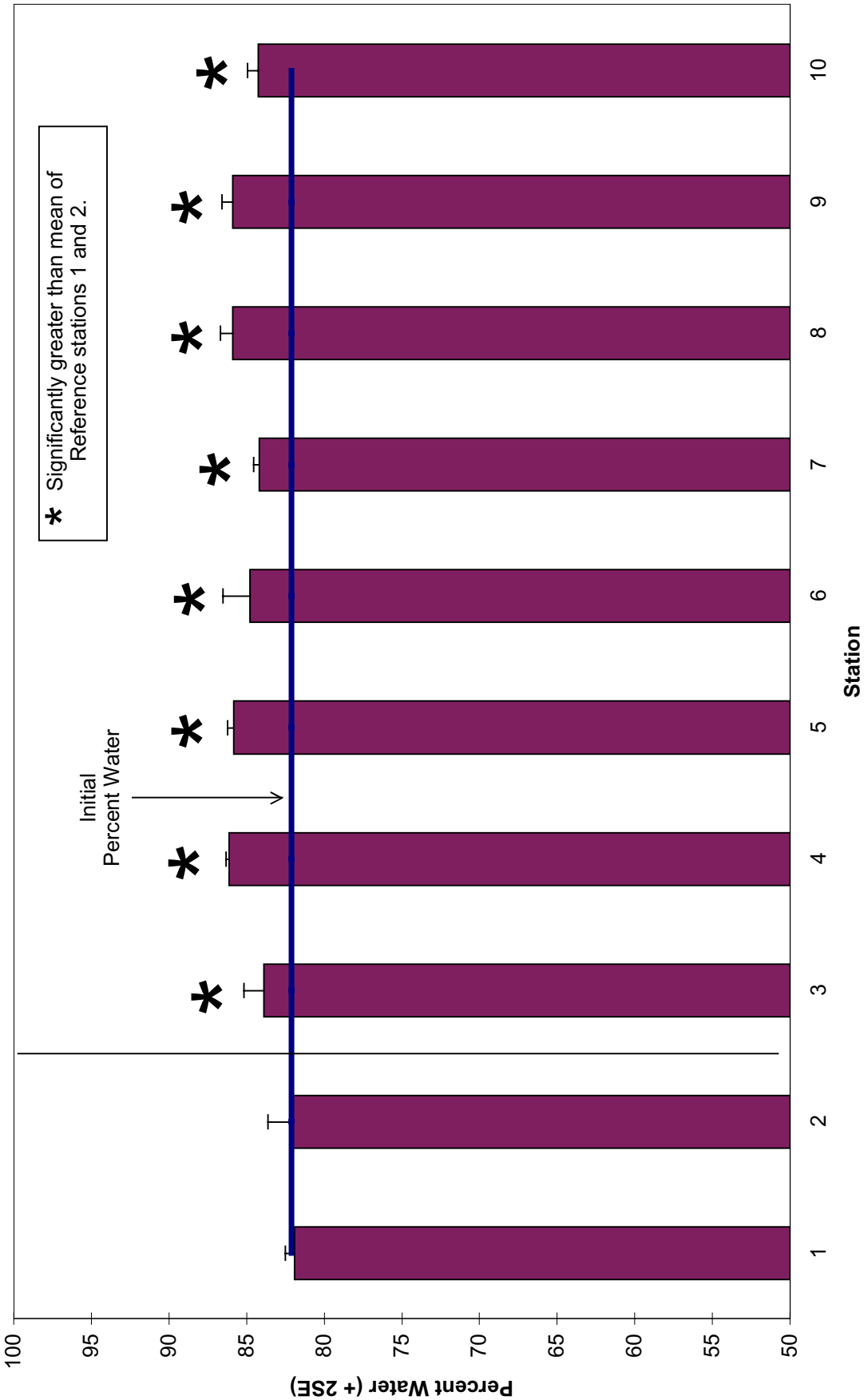


Figure B-6. End-of-Test Percent Water in Caged Oysters



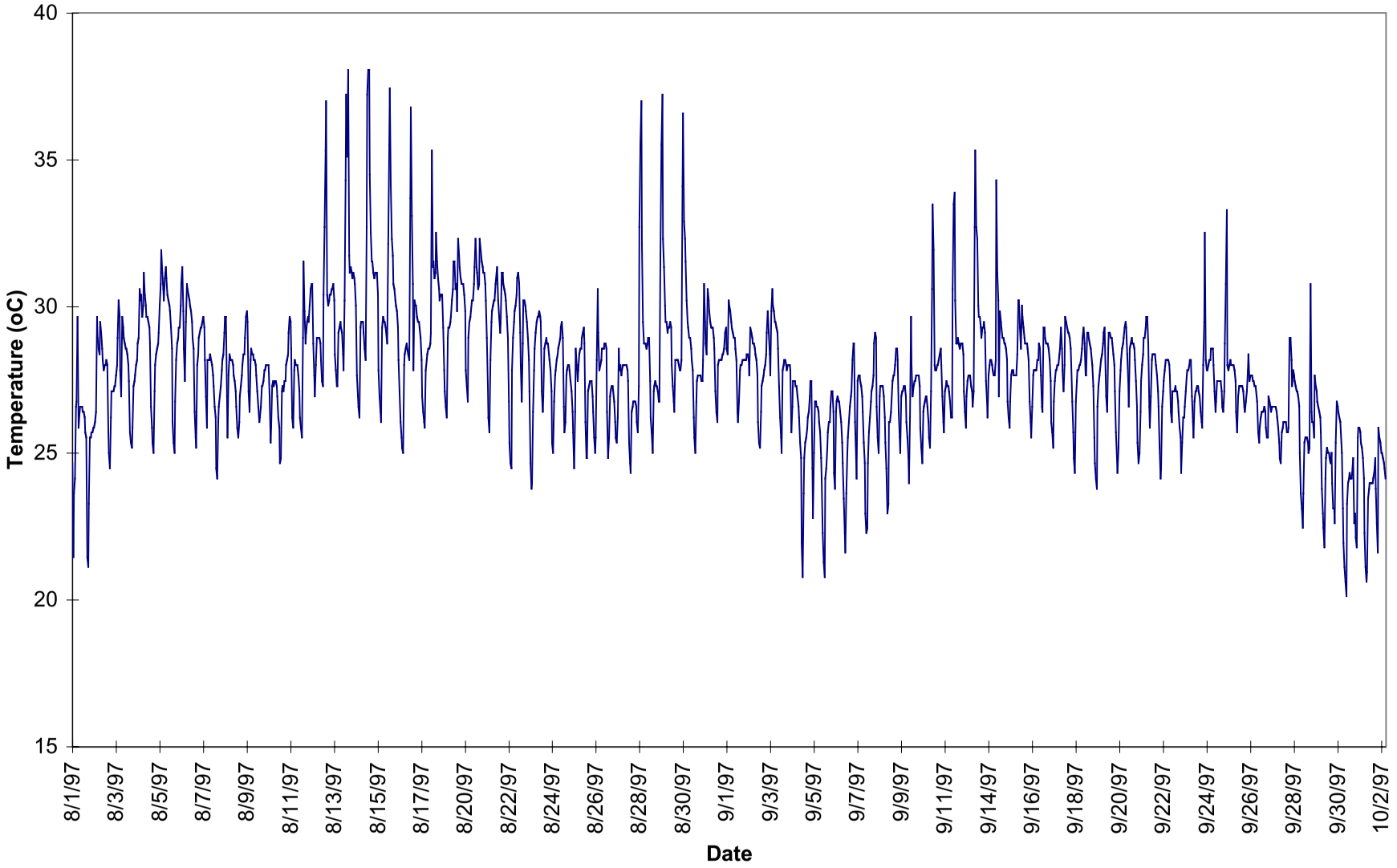


Figure B-7.1. LCP Station 1

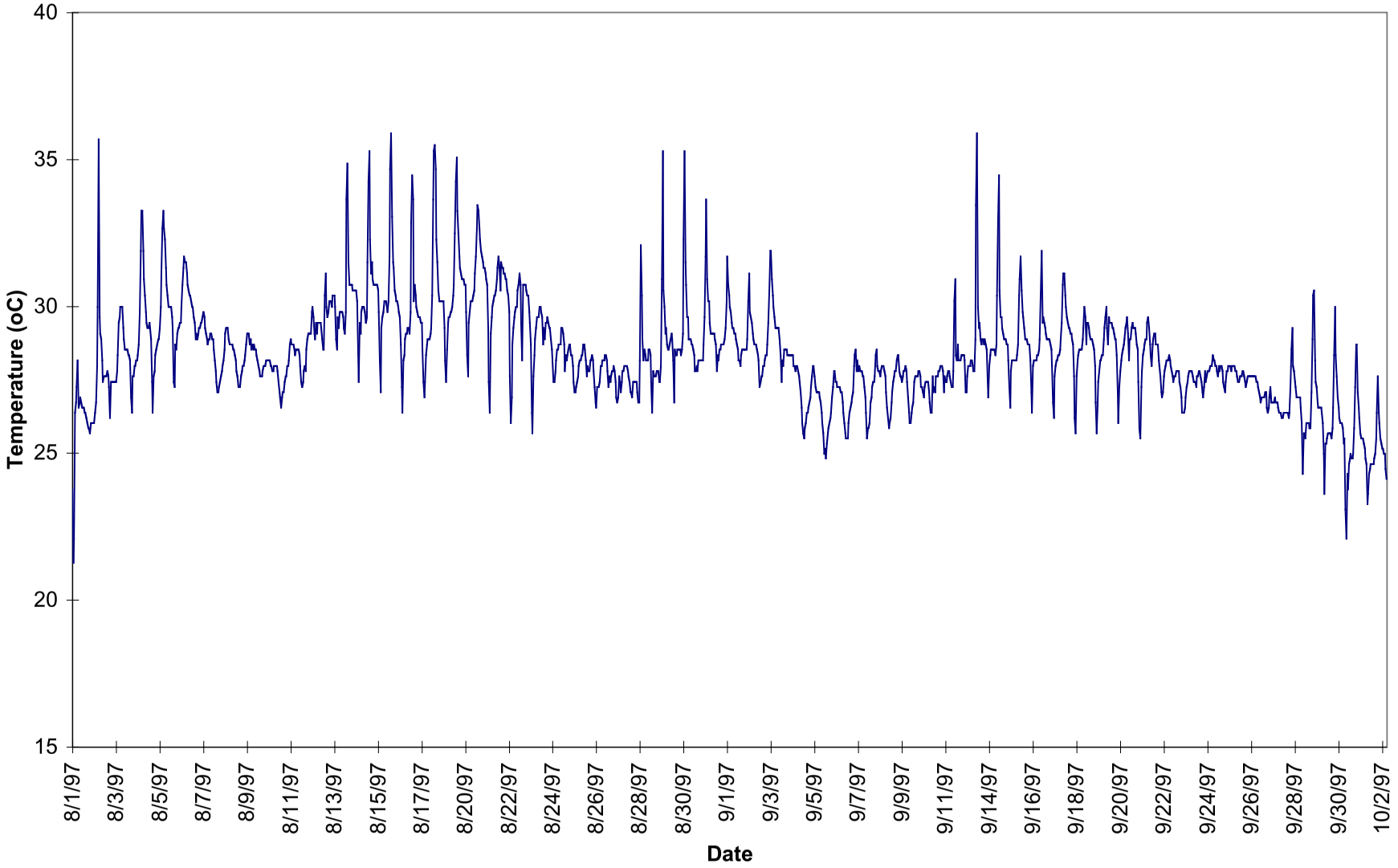


Figure B-7.2. LCP Station 2

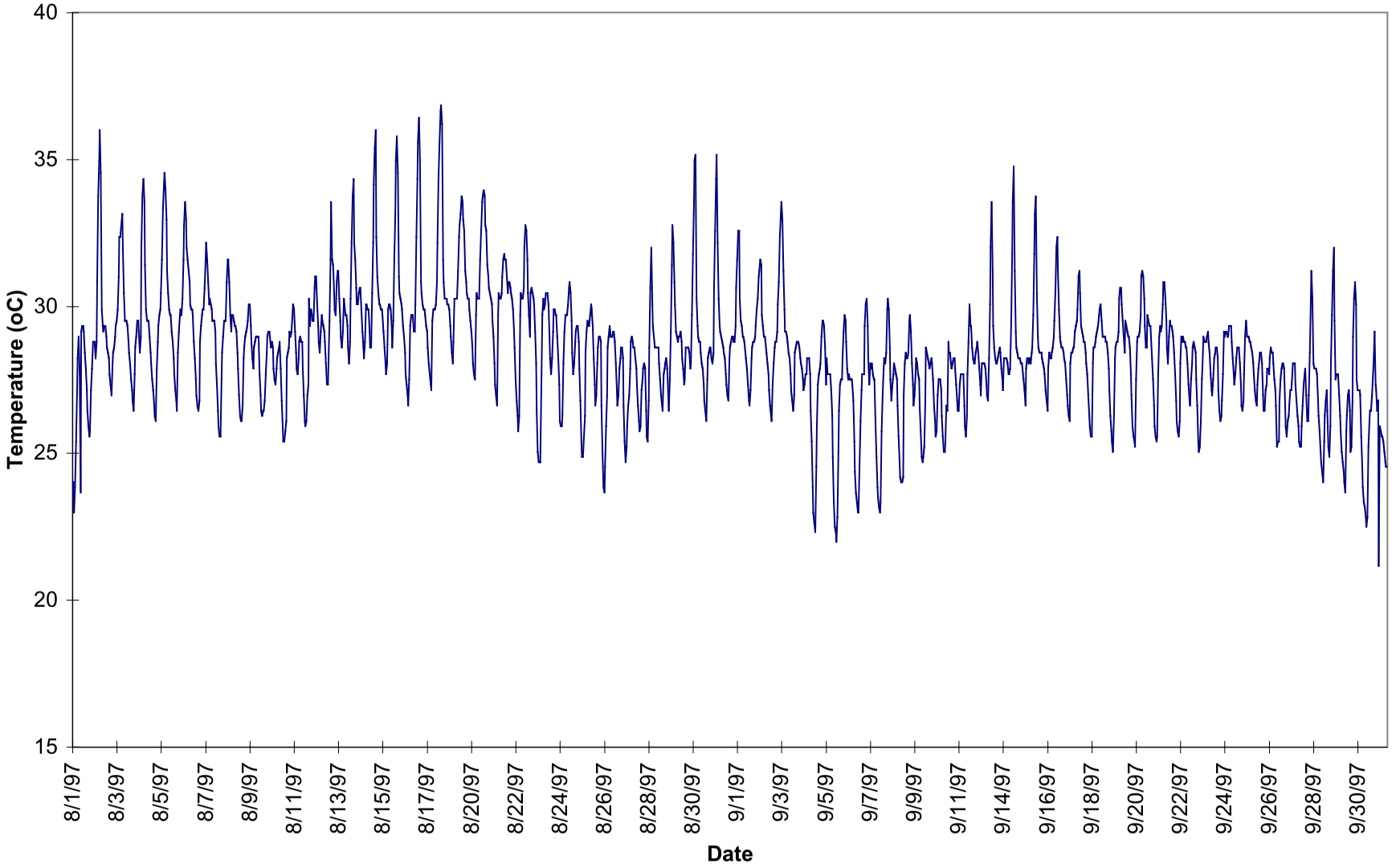


Figure B-7.3. LCP Station 3

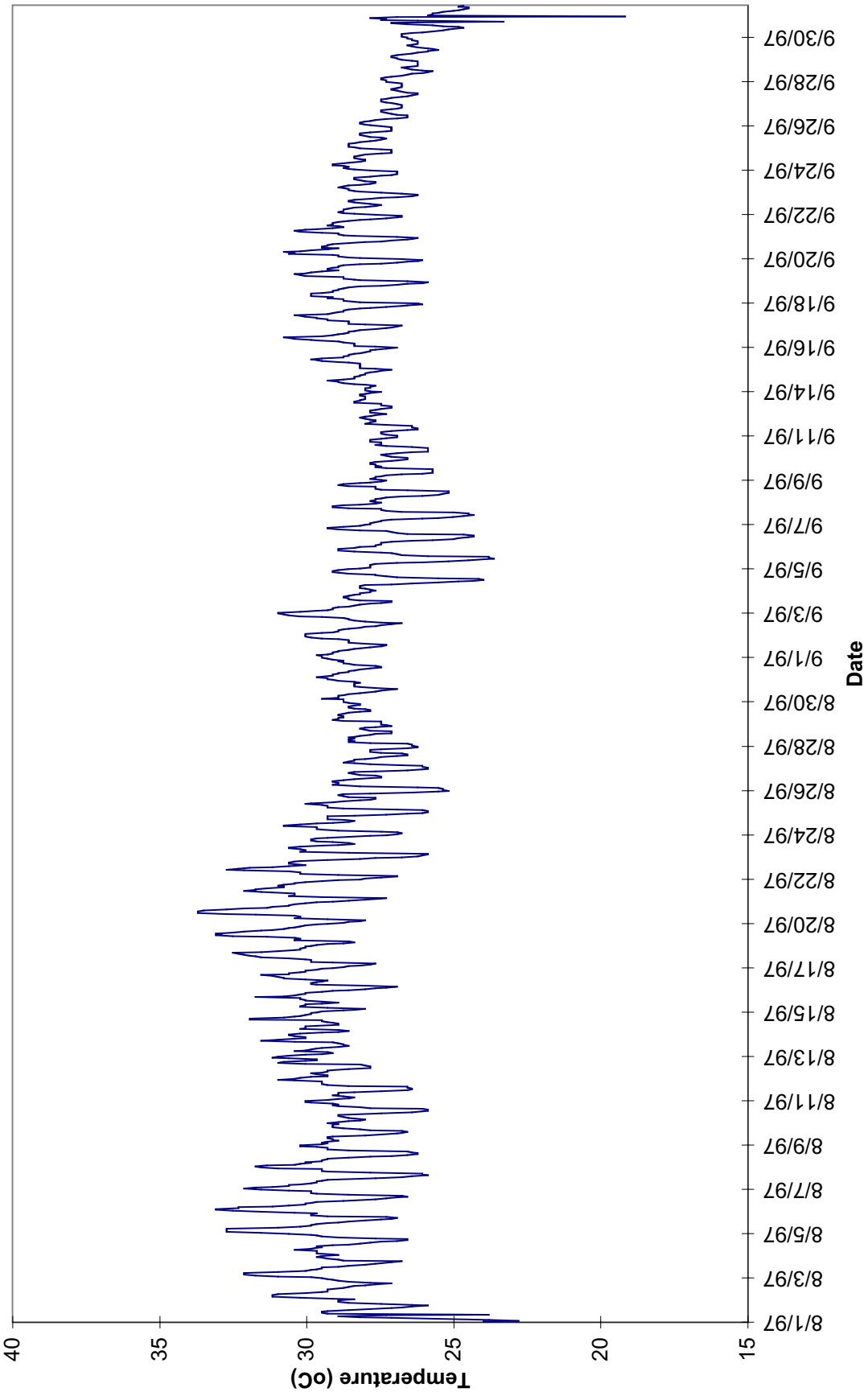


Figure B-7.4. LCP Station 4

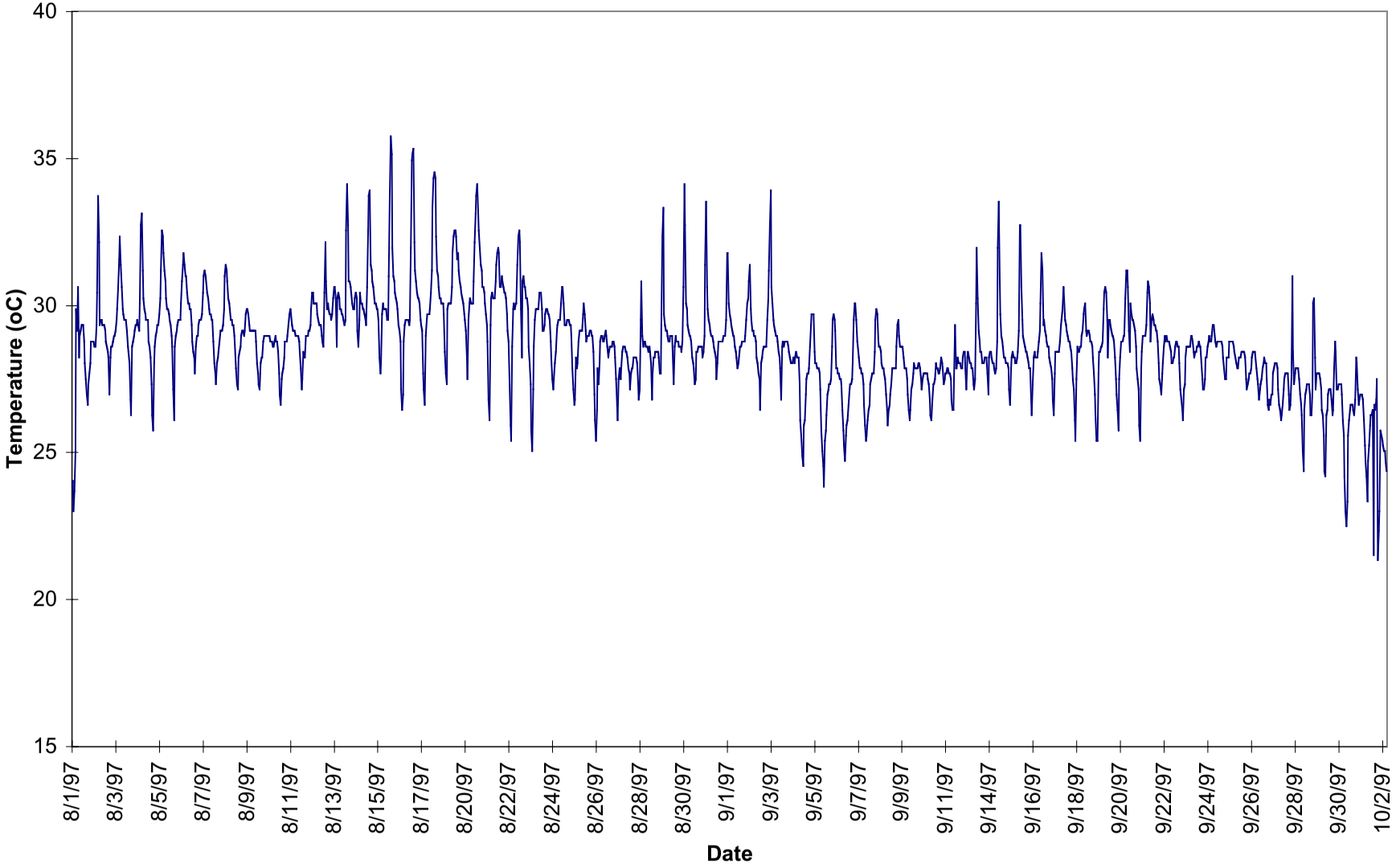


Figure B-7.5. LCP Station 5

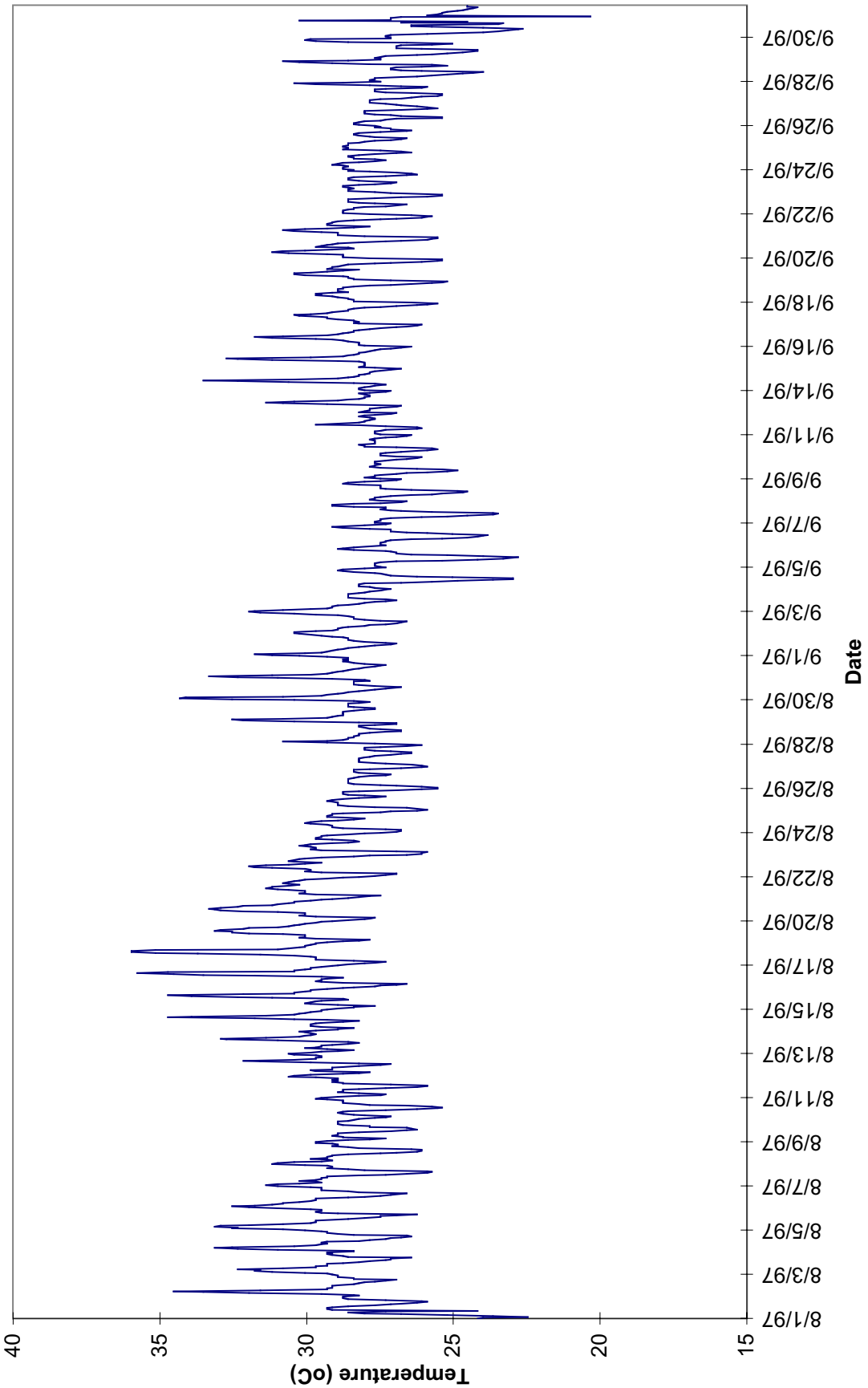


Figure B-7.6. LCP Station 6

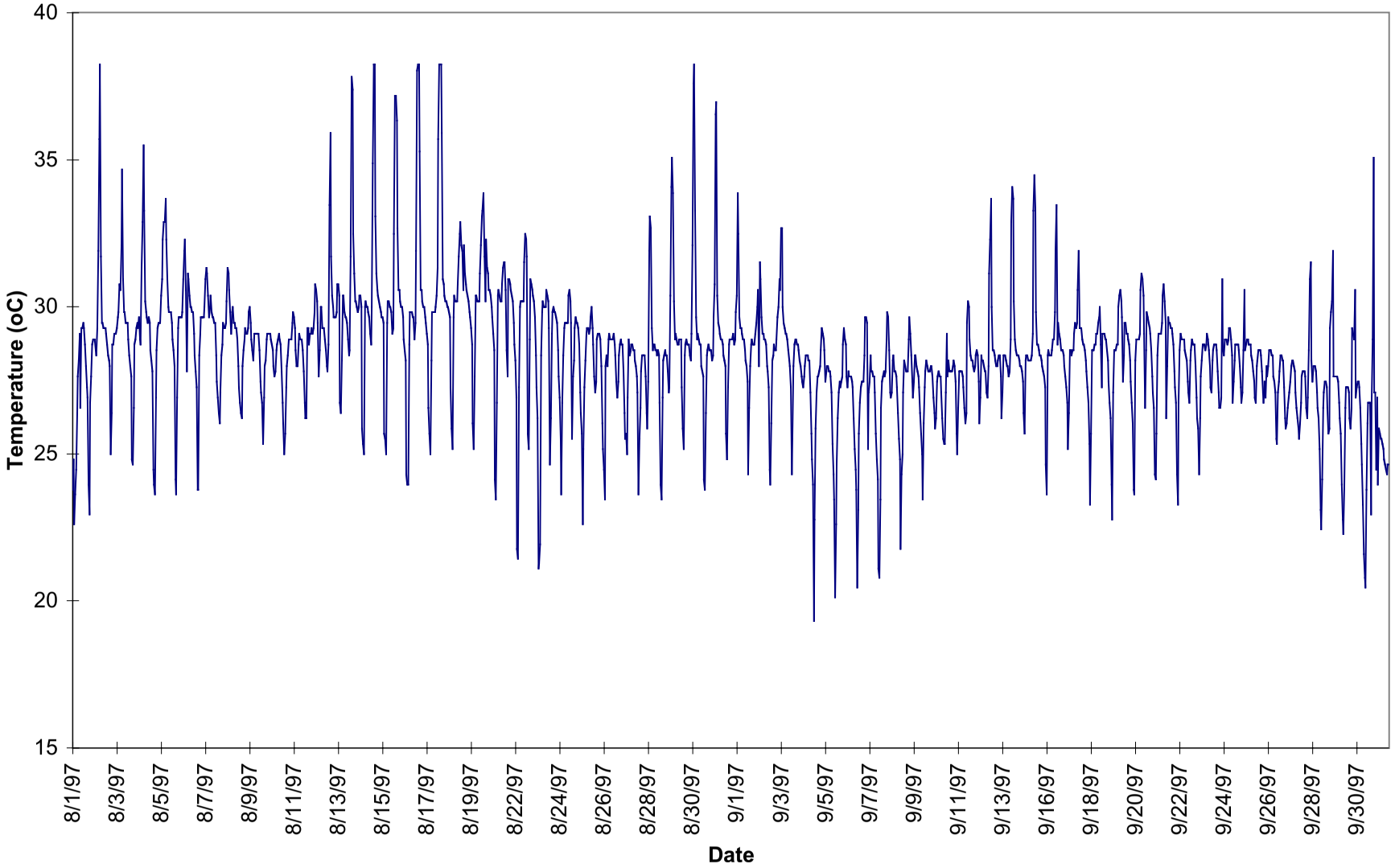


Figure B-7.7. LCP Station 7

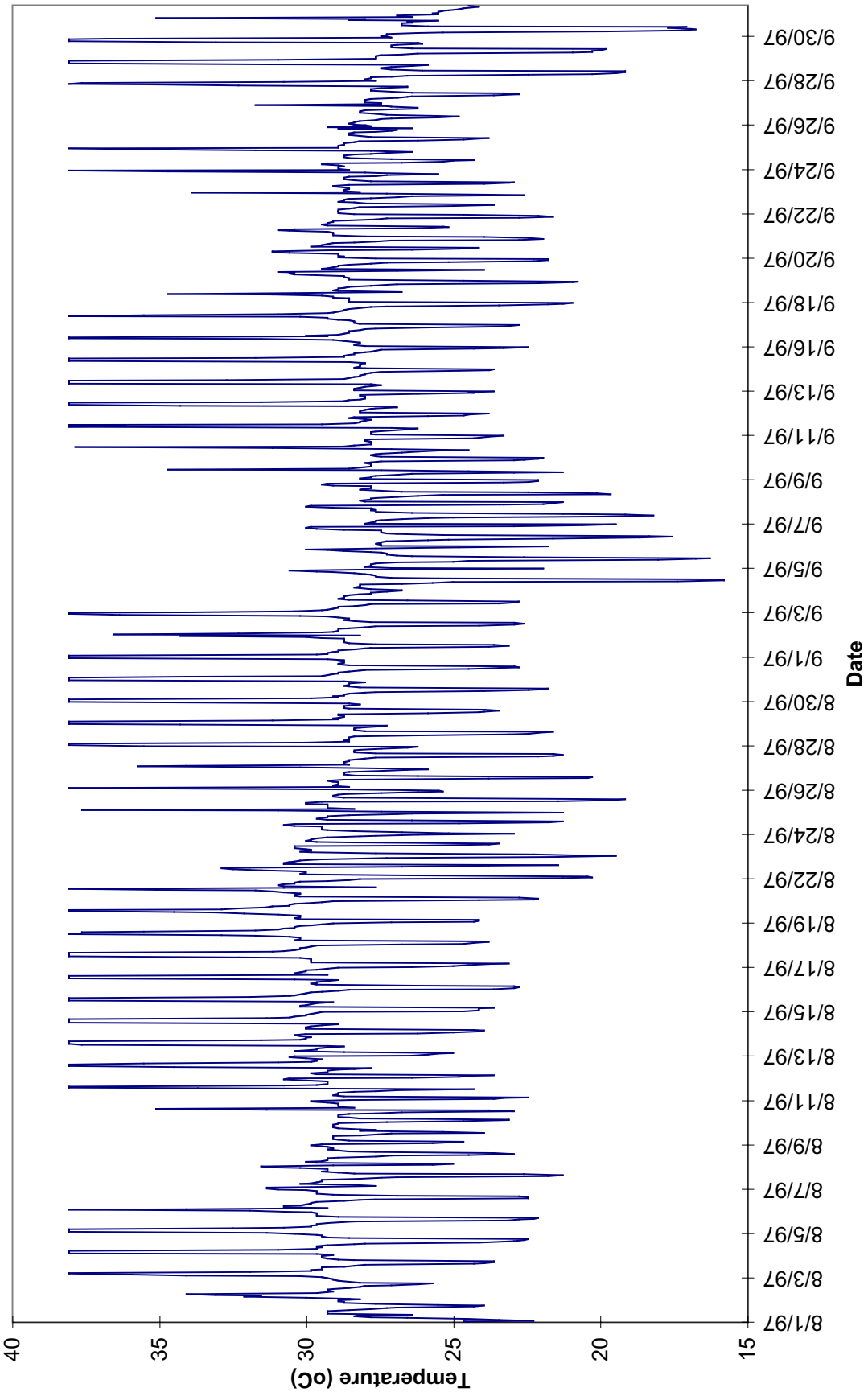


Figure B-7.8. LCP station 8

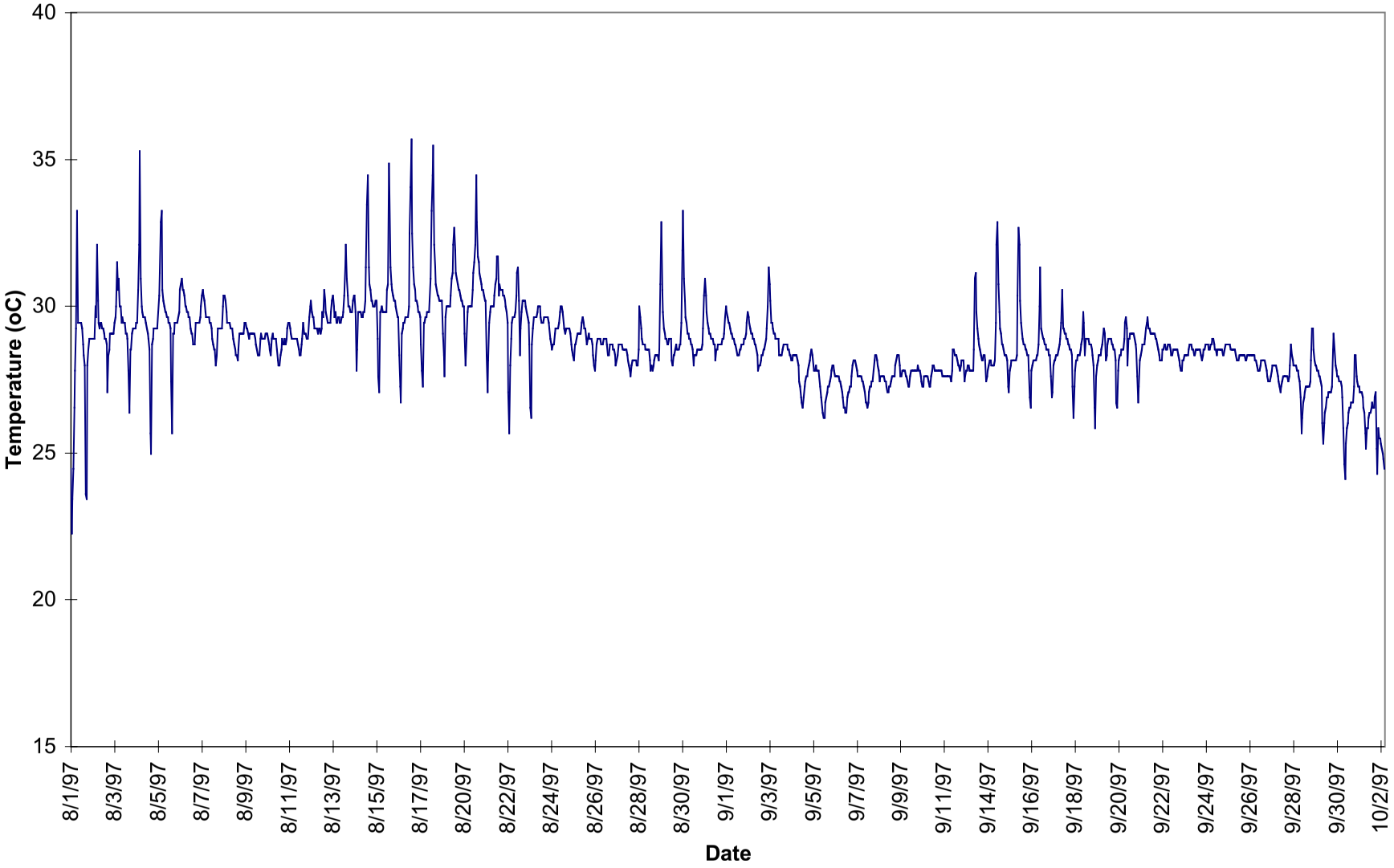


Figure B-7.9. LCP Station 9

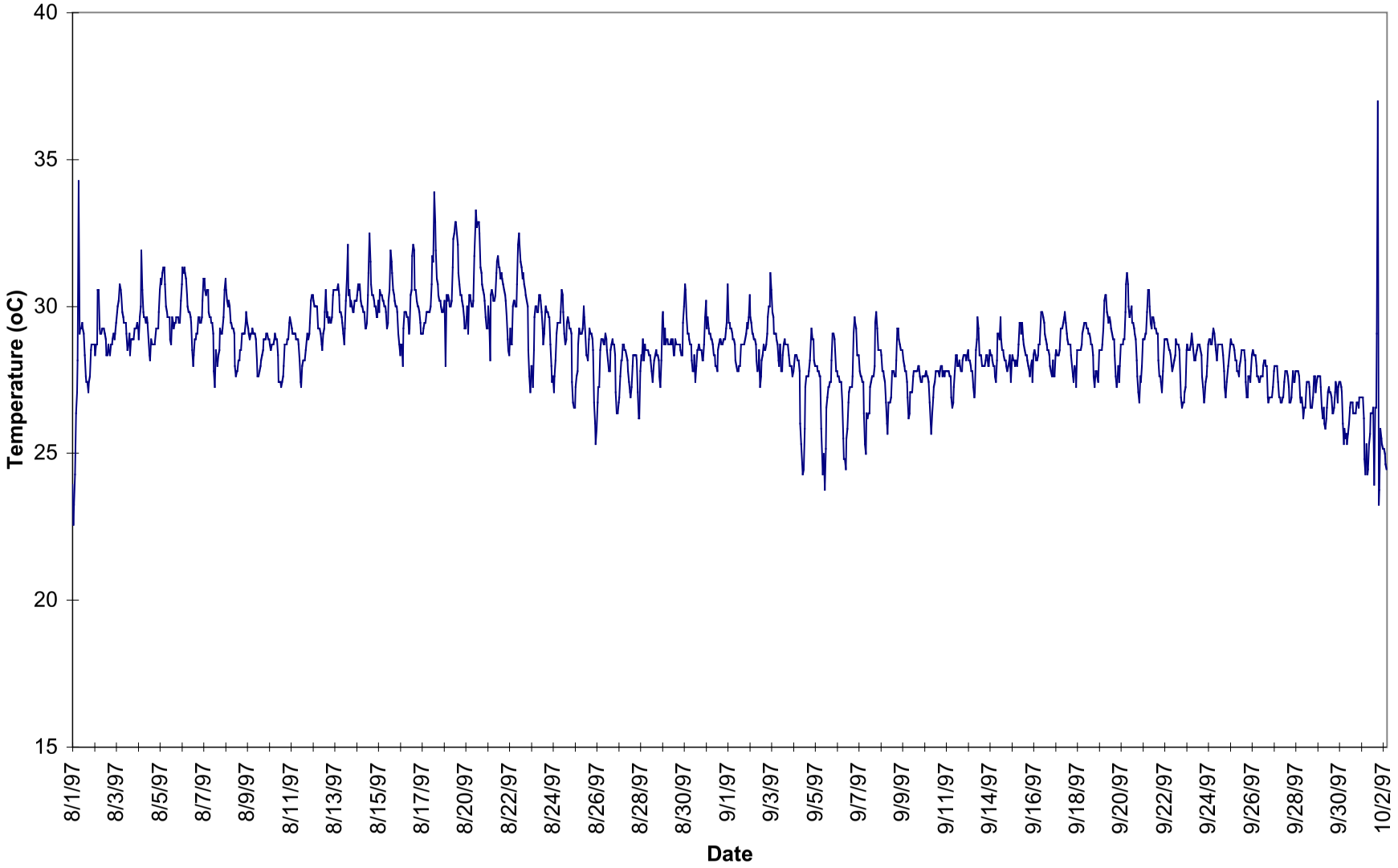


Figure B-7.10. LCP Station 10

Figure B-8. LCP Daily Averages