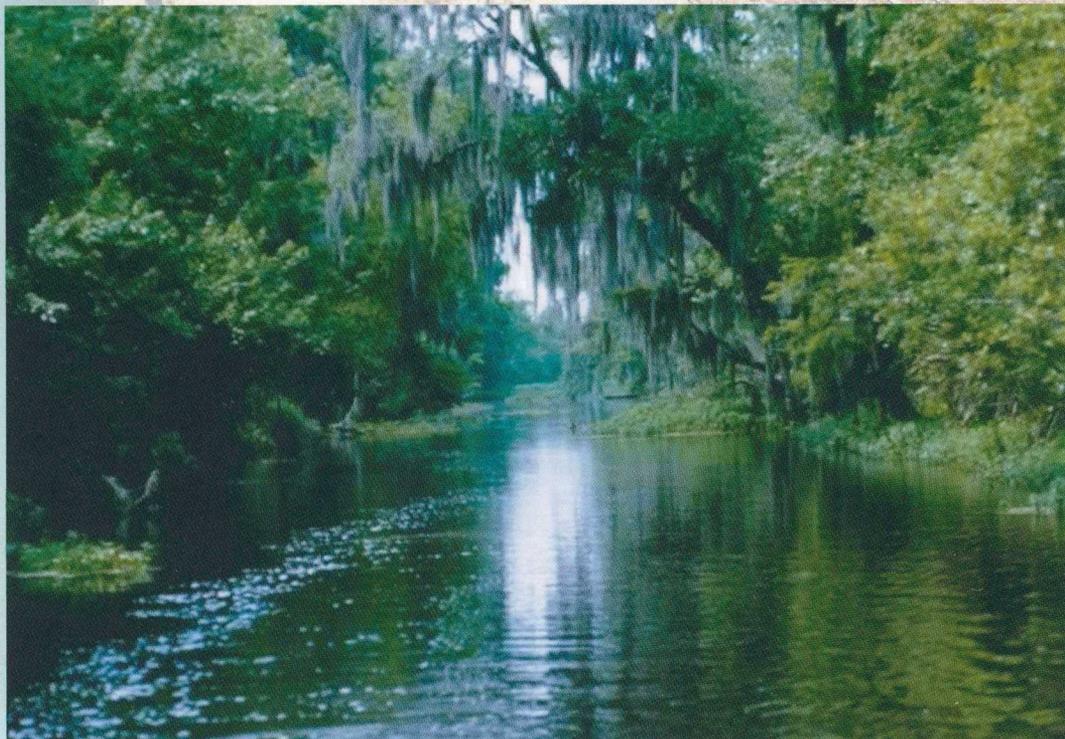


In cooperation with the
NATIONAL PARK SERVICE



Assessment of Total Mercury and Methylmercury Concentrations at the Barataria Preserve of Jean Lafitte National Historical Park and Preserve, Louisiana, During Dredging Operations, 2001-02

SCIENTIFIC
INVESTIGATIONS REPORT
2005-5093





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By Kevin J. Grimsley and Christopher M. Swarzenski

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Scientific Investigations Report 2005-5093

**U.S. Department of the Interior
U.S. Geological Survey**

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Suggested citation:

Grimsley, K.J., and Swarzenski, C.M., 2005, Assessment of total mercury and methylmercury concentrations at the Barataria Preserve of Jean Lafitte National Historical Park and Preserve, Louisiana, during dredging operations, 2001-02: U.S. Geological Survey Scientific Investigations Report 2005-5093, 13 p.

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Conversion Factors, Datum, and Abbreviated Units

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
acre	0.004047	square kilometer (km ²)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
 $^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$

Horizontal coordinate information is referenced to the North American Datum of 1927.

Abbreviated units:

grams per liter (g/L)

micrograms per liter ($\mu\text{g/L}$)

milligrams per liter (mg/L)

milliliter (mL)

nanograms per gram (ng/g)

nanograms per liter (ng/L)

Assessment of Total Mercury and Methylmercury Concentrations at the Barataria Preserve of Jean Lafitte National Historical Park and Preserve, Louisiana, During Dredging Operations, 2001-02

By Kevin J. Grimsley and Christopher M. Swarzenski

Abstract

The Barataria Preserve of Jean Lafitte National Historical Park and Preserve is a wetland ecosystem southwest of New Orleans, Louisiana. A study from May 2001 to May 2002 assessed the effects of a coastal restoration project on concentrations of total mercury and methylmercury in areas within the Preserve. The project involved filling canals with their spoil banks and dredge material. The study consisted of three phases to determine (1) background concentrations of total mercury and methylmercury in the area where canals would be modified and the area in Lake Salvador where dredge material would be removed during the project; (2) the total mercury and methylmercury concentrations in and adjacent to the two canals where the spoil banks had been removed, but prior to placement of dredge material from Lake Salvador; and (3) the total mercury and methylmercury concentrations during the dredging operation, at both the intake and output of the dredge. Sixteen sample-collection sites, including two control sites, were selected to monitor potential changes in concentrations of total mercury and methylmercury within the study area and included open water (lake), canals, and peat marsh. Mercury concentrations from analyses were compared to established guidelines for mercury in drinking water, ambient (natural) water, and sediment.

During phase 1, all concentrations of total mercury in samples analyzed were below guidelines. The prepared elutriate samples, intended to simulate the dredge material that would be deposited in Middle Access Canal, indicated that the slurry created from dredging operations in this area would not increase concentrations of mercury above the guidelines.

Total mercury concentrations in samples collected during phase 2 also did not exceed guidelines. Samples collected at different depths in the peat marsh indicated an increase in the affinity of mercury to the particulate fraction of samples with respect to depth and an opposite trend in 3 out of 4 samples in the filtered fraction. Also, bottom-material samples in the marsh had higher total mercury concentrations at deeper sam-

pling locations, but higher methylmercury concentrations at the shallow locations, indicating a higher rate of methylation at shallow depths.

During phase 3, none of the total mercury concentrations at the dredge intake exceeded guidelines. At the dredge output, the filtered total mercury concentration was below guidelines, and the total mercury concentration expressed as bottom material was below the guideline for sediment (bottom material). Although the unfiltered total mercury concentration at the dredge output did exceed the guidelines for drinking water and ambient water, these are not appropriate standards by which to evaluate a water sample with such high particulate concentrations.

From phase 1 to phase 2, concentrations of total mercury in bottom material decreased at site 6 (in Middle Access Canal), but increased slightly at site 8 (in North Keyhole Canal). Methylmercury concentrations increased in bottom material at both sites. Total mercury and methylmercury concentrations in bottom material were higher in samples from the marsh adjacent to the filled canals than from the canals themselves. These analyses indicate that, although there was no overall increase in total mercury in the filled canals, there was an increase in methylmercury.

The average total mercury concentration at the phase 2 marsh sites was lower than the average at the control marsh sites. This indicates that the spoil-bank removal between phases 1 and 2 did not increase mercury concentrations in the marshes adjacent to the filled canals.

Introduction

The Barataria Preserve of Jean Lafitte National Historical Park and Preserve includes about 20,000 acres (D.P. Muth, Jean Lafitte National Historical Park and Preserve, written commun., 2005). The Preserve is a wetland ecosystem about 15 mi southwest of New Orleans, Louisiana. The natural landscape of marsh and forested swamp in the Barataria Preserve has been

2 Total Mercury and Methylmercury at Barataria Preserve

altered by the construction of canals for oil and gas development. The associated spoil banks, built from the material dredged from the canal and placed on top of the marshes, are topographically high relative to marsh elevation. The canals and their spoil banks have affected the local hydrology, and have provided a substrate for invasive exotic plants such as the Chinese tallow tree (*Sapium sebiferum* L.).

Background

In 1999, the National Park Service (NPS) proposed a pilot study for a coastal restoration project to backfill two canals in the Barataria Preserve by removing their associated spoil banks. The proposal called for the restoration of the canals and spoil banks to the natural marsh level to foster the return of emergent marsh vegetation. To accomplish this, the spoil banks were to be pushed into the canals and the canal openings plugged. In one of the canals, bottom material would be dredged from nearby Lake Salvador and placed on top of the spoil-bank material to complete the raising of the canal to the natural marsh level. The two treatments, with and without additional dredge material, were to be compared for effectiveness.

The widespread presence of mercury in the environment has been attributed to air pollution. In surface water, mercury can be brought to the sediments by particle settling, then later released by diffusion or resuspension. Dredging may resuspend and remobilize the mercury, increasing its availability to the food chain. Because methylmercury undergoes bioaccumulation, the larger predatory gamefish typically have the highest mercury levels. Human exposure to mercury and methylmercury can cause severe illness and death, and fish consumption advisories are common in many states (Krabbenhoft and Rickert, 1995). Swarzenski (2003) and Swarzenski and others (2004) documented total mercury concentrations in surface water, bottom material, and fish tissue collected within the Barataria Preserve. Contamination of fish tissue could result if mercury concentrations increased substantially during the pilot study. Such contamination could pose a health hazard to visitors who use the waters of the Preserve for recreational fishing.

Wetlands are known to be mercury-sensitive ecosystems because of their relatively efficient conversion of inorganic mercury into bioavailable methylmercury. It is not known how coastal restoration projects in these sensitive ecosystems affect the fate and cycling of mercury. Therefore, NPS wanted to document potential changes to the wetland environment that might occur during dredging operations, and was particularly interested in whether the dredging of bottom material and disturbance of spoil banks would cause mercury or methylmercury to be released into the aquatic environment.

In 2001, the U.S. Geological Survey (USGS), in partnership with NPS, began a study to assess the effects of the coastal restoration project on total mercury and methylmercury concentrations in the area. The objectives of this study were to (1) assess the potential for the release of mercury and methylmercury from bottom material into surface waters; (2) monitor concentrations of mercury and methylmercury in surface waters

during the dredging operation; and (3) assess the potential for release of methylmercury from pore water in marshes adjacent to the affected spoil banks.

Purpose and Scope

This report presents the findings of an assessment of total mercury and methylmercury concentrations at the Barataria Preserve, conducted by the USGS in partnership with the NPS from May 2001 to May 2002. The report documents the effects of a coastal restoration project on the total mercury and methylmercury concentrations in and near the project area. Analytical results for surface-water, pore-water, bottom-material, and elutriate samples from 14 sites are presented in tables organized according to the three phases of the study (see "Approach and Methods" section). Analytical results for samples from 2 control sites are listed in a separate table. Results for the three study phases are discussed.

Description of Study Area

The Barataria Preserve (fig. 1) is a wetland ecosystem containing swamp forests and floating peat marshes. The peat marshes have developed with very little influx of river water and associated clay and silt sediments. The upper 2 to 3 ft of this marsh type can adjust vertically to changes in surface-water levels, creating a hydrology and an exchange of solutes with adjacent surface waters that differ significantly from those occurring in rooted marshes (Swarzenski and Swenson, 1994).

Louisiana's coastal plain includes large areas of floating peat-marsh habitat, and is one of a very few temperate and subtropical coastal areas, globally, where this marsh type occurs extensively. Other areas include the Danube delta in Romania and the Sudd swamps on the Nile. This unique wetland ecosystem is represented extensively in the Barataria Preserve (Swarzenski and others, 1991).

The wetland landscape at the Barataria Preserve has been altered by both natural and anthropogenic forces at local and regional scales. Storm runoff into the Preserve has increased as suburban neighborhoods continue to develop and grow along the Preserve's boundaries. The effects of suburban runoff on water quality, and on the wetland ecosystem in the Preserve, currently are unknown. Regionally, severe land-loss along Louisiana's coastline is affecting the ecological integrity of a very productive estuarine zone. Louisiana's commercial fin and shell fisheries are ranked second in value in the nation (National Oceanic and Atmospheric Administration, 2003).

Acknowledgments

The authors thank the National Park Service for their cooperation and assistance throughout this study. We especially thank David Muth, Chief of Resource Management, Barataria Preserve of Jean Lafitte National Historical Park and Preserve, for his assistance.

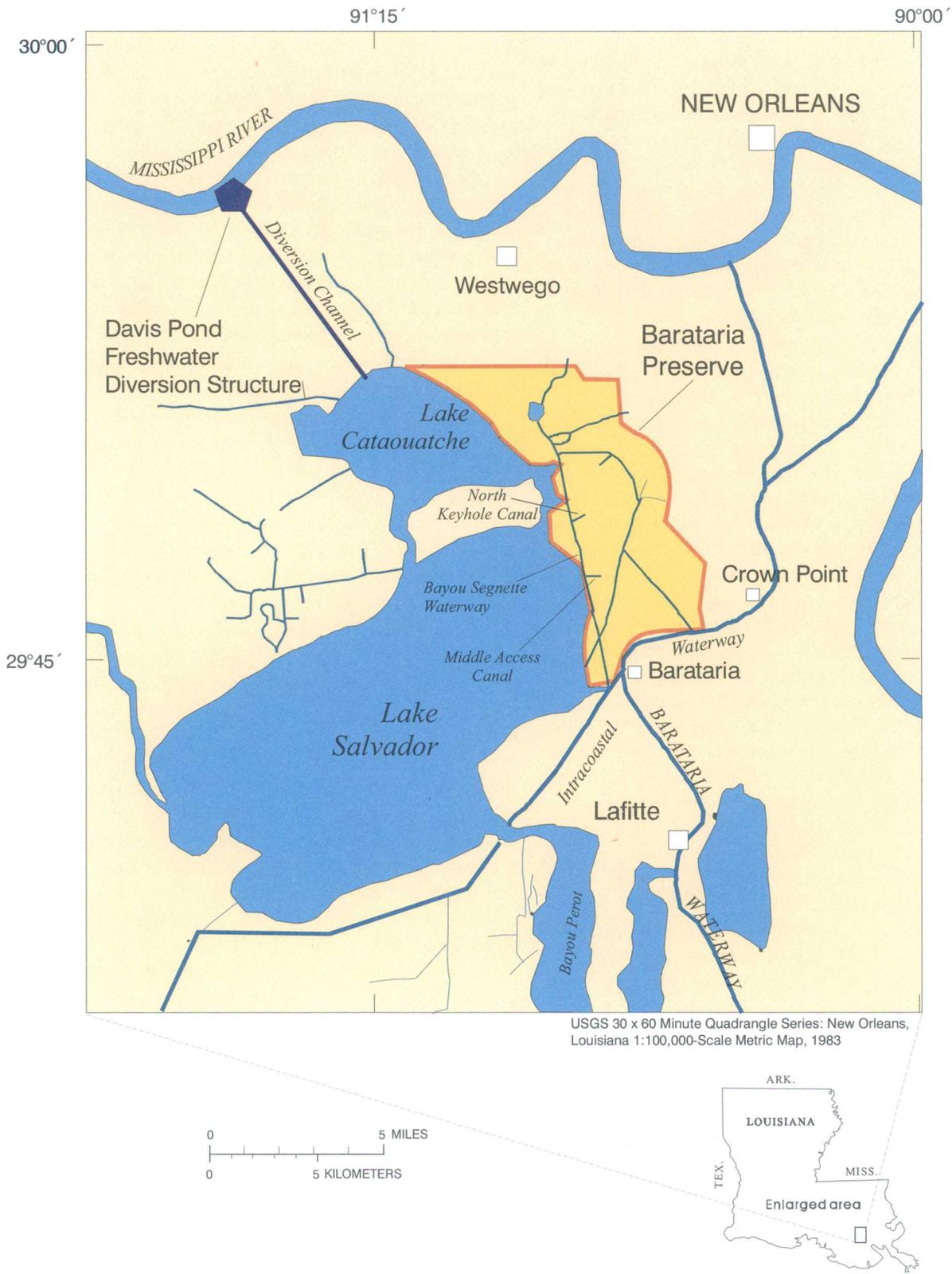


Figure 1. Location of the Barataria Preserve, Jean Lafitte National Historical Park and Preserve, Louisiana.

Approach and Methods

The study consisted of three phases intended to determine (1) background concentrations of total mercury and methylmercury in the area where canals would be modified and the area in Lake Salvador where dredge material would be removed during the project; (2) the total mercury and methylmercury concentrations in and adjacent to the two canals where the spoil banks had been removed, but prior to placement of dredge material from Lake Salvador; and (3) the total mercury and methylmercury concentrations during the dredging operation, at both the intake and output of the dredge. In addition, pore water samples were collected from control sites in the marsh to assess the potential for release of methylmercury to the adjacent area.

Sixteen sample-collection sites were selected to monitor potential changes in concentrations of total mercury and methylmercury within the study area (fig. 2). The locations were selected based on details of the coastal restoration project, and included open water (lake), canals, and peat marsh. The sites are listed and described in table 1. Sites 1-6 and 8 were sampled in phase 1, prior to spoil-bank removal and dredging. Sites 1-5 were in Lake Salvador, where dredging was to occur. During phase 1, the two canals that were to be filled, Middle Access Canal and North Keyhole Canal, were inaccessible and sites 6 and 8 were sampled in the Bayou Segnette Waterway at the mouths of the two canals. During phases 2 and 3, the canals were accessible and sites 6 and 8 were moved approximately 200 ft into the canals. During phase 2, after spoil-bank removal, sites 6-13 were sampled. Sites 6-9 were in the canals that were being filled, and sites 10-13 were about 100 ft into the peat marsh adjacent to each side of both canals. For phase 3, sites 6 and 14 were sampled during the dredging process. Site 6, in Middle Access Canal, was sampled during the placement of dredge material approximately 1,000 ft away in the canal. Site 14 was in Lake Salvador where the dredge was operating, and was subdivided into three locations surrounding the dredge at a distance of approximately 100 ft. Sites 15 and 16 were control sites in an area of the Preserve that was unaffected by dredging, but similar to the marsh adjacent to the canals that were being filled.

All samples discussed in this report were collected and processed by USGS personnel. Techniques used for cleaning and preparation of all equipment utilized in the collection of samples were described by USGS (1997-present). All sample preparation and analyses were performed by the USGS Mercury Research Laboratory in Middleton, Wisconsin, using methods described by Olson and DeWild (1999) and by DeWild and others (2002). A total of 137 field samples, 20 replicate field samples, and 6 replicate laboratory samples were analyzed.

All surface-water samples were collected about 1 to 2 in. below the water surface, using clean Teflon[®] containers. Sample containers were opened under water to avoid potential atmospheric contamination. Samples were chilled at 4 °C for preservation. Each surface-water sample collected during phase 1

was divided into two subsamples, one of which was sent to the laboratory for analysis; the other was used to create a suspension that simulated dredged material (elutriate). Surface-water samples sent to the laboratory during phase 1 were filtered and analyzed for filtered total mercury, filtered methylmercury, and particulate methylmercury (there was not enough particulate matter to analyze for both total mercury and methylmercury). All but one of the surface-water samples collected in phases 2 and 3 were analyzed for filtered total mercury, filtered methylmercury, particulate total mercury, and particulate methylmercury. The exception was a sample collected from site 6 during phase 3, during dredging. This sample was too turbid to be filtered by the methods necessary to analyze the particulate fraction; therefore, it was analyzed only for filtered and unfiltered total mercury and methylmercury.

Pore water samples were collected during phase 2 and at the control sites using 4-mm (inside diameter), acid-rinsed, acrylic tubing with 2-mm holes drilled through the side, about 1 to 2 in. from one end, to allow water to pass through. The acrylic tubing was attached to several feet of acid-rinsed, flexible plastic tubing leading to a peristaltic pump. The water was pumped from two depths, 2 and 14 in., and collected in clean Teflon[®] bottles. The samples were chilled at 4 °C and shipped to the laboratory to be analyzed for either filtered or unfiltered total mercury and methylmercury.

During phase 1, a 2-in.-diameter, clear, acid-rinsed, polyvinyl chloride (PVC) pipe was used to collect a 4-ft core of bottom material from each site sampled. Each core, except from sites 6 and 8, was mixed manually to ensure homogeneity, divided into two subsamples, and chilled at 4 °C for preservation. One subsample from each site 1-5, and the entire sample from sites 6 and 8, were chilled at 4 °C immediately after collection and sent to the laboratory, where they were analyzed for total mercury and methylmercury; each remaining subsample was mixed with surface water to create an elutriate sample. During phase 2, approximately the top 2 in. of bottom material was collected from the two canals by scooping the material directly with Teflon[®] sample containers. An approximate 2-ft core of bottom material was collected from the marsh sites sampled during phase 2 and from the control sites, using 2-in.-diameter, white, PVC pipe. An acid-rinsed ceramic knife was used to remove 125 mL of material from the center of the core (material not in contact with pipe walls), at depths of 2 and 14 in., and place into Teflon[®] containers. The 2- and 14-in. depths were selected to monitor the expected range of disturbed material near the marsh sampling locations. All of these samples were chilled at 4 °C immediately after collection and shipped to the laboratory to be analyzed for total mercury and methylmercury.

Elutriate samples, intended to simulate the dredge material that would be deposited into Middle Access Canal, were made according to methods described in Keeley and Enger (1974) from water and bottom material collected at sites 1-5. For each elutriate sample, a subsample of bottom material was mixed with a subsample of surface water from the same site in a 1:4



Photograph source: Digital Orthophoto Quarter Quadrangle, U.S. Geological Survey Identification number c2909015-16-23-24; accessed 5/29/04 at URL: <http://www.atlas.lsu.edu>



EXPLANATION
 14 ● Site location and number



INDEX MAP

Figure 2. Location of sample-collection sites at the Barataria Preserve, Jean Lafitte National Historical Park and Preserve, Louisiana (see fig. 1).

6 Total Mercury and Methylmercury at Barataria Preserve

Table 1. Sample-collection sites and description of samples collected at the Barataria Preserve, Jean Lafitte National Historical Park and Preserve, Louisiana, 2001-02.

[NA, not applicable]

Site no. (fig. 2)	Site type	Location		Types of samples	Phase ¹
		Latitude	Longitude		
1	Lake	29°47'20"	90°09'24"	Surface water, bottom material, elutriates	1
2	Lake	29°47'26"	90°09'25"	Surface water, bottom material, elutriates	1
3	Lake	29°47'32"	90°09'33"	Surface water, bottom material, elutriates	1
4	Lake	29°47'40"	90°09'40"	Surface water, bottom material, elutriates	1
5	Lake	29°47'42"	90°09'50"	Surface water, bottom material, elutriates	1
6	Canal	29°47'08"	90°08'55"	Bottom material	1
				Surface water, bottom material	2
				Surface water	3
7	Canal	29°47'04"	90°08'39"	Surface water, bottom material	2
8	Canal	29°48'14"	90°09'15"	Bottom material	1
				Surface water, bottom material	2
9	Canal	29°48'22"	90°08'58"	Surface water, bottom material	2
10	Marsh	29°47'09"	90°08'53"	Bottom material, pore water	2
11	Marsh	29°47'03"	90°08'37"	Bottom material, pore water	2
12	Marsh	29°48'15"	90°09'16"	Bottom material, pore water	2
13	Marsh	29°48'21"	90°08'57"	Bottom material, pore water	2
14	Lake	29°47'12"	90°09'25"	Surface water	3
15	Marsh (control site)	29°49'40"	90°08'29"	Bottom material, pore water	NA
16	Marsh (control site)	29°49'44"	90°08'20"	Bottom material, pore water	NA

¹ Phase 1 samples were collected May 15, 2001, before spoil-bank removal and dredging; phase 2 samples were collected February 20, 2002, after spoil-bank removal but before placement of dredge material; phase 3 samples were collected May 14, 2002, during dredging. Control site samples were collected May 14, 2002, but these sites were not affected by the coastal restoration project and, therefore, the sample collection was not associated with a phase.

volumetric ratio of bottom material to surface water. The bottom material and water were placed in an acid-rinsed, Teflon[®]-coated bowl and mechanically mixed at a constant rate with an acid-rinsed, Teflon[®]-coated stirrer for 30 min. The mixture was then allowed to stand for 1 hr, after which it was decanted. The decantate was then centrifuged in a clean, Teflon[®] test tube, and decanted a second time, into a clean, Teflon[®] collection bottle. The second decantate was chilled at 4 °C and shipped to the laboratory to be filtered and analyzed for filtered and particulate total mercury and methylmercury.

Total Mercury and Methylmercury Concentrations

Analytical results for the surface-water, pore-water, bottom-material, and elutriate samples, including the replicate samples, are presented in tables 2, 3, and 4 according to the three phases of the study. Data from the control sites are pre-

sented in table 5. All analyses performed on filtered and unfiltered samples have a detection limit of 0.040 ng/L. Detection limits for analyses of particulate samples change from analysis to analysis. Therefore, the appropriate detection limit is provided with each particulate concentration in tables 2-5.

The U.S. Environmental Protection Agency (USEPA) has not established guidelines for mercury and methylmercury concentrations in ambient water and bottom material. However, the USEPA (2003) has established a Maximum Contaminant Level (MCL) of 0.002 mg/L (2,000 ng/L) for mercury (inorganic) in drinking water. The Canadian Council of Ministers of the Environment (CCME) (1999) has established a guideline for mercury in drinking water of 1 µg/L (1,000 ng/L). The CCME (1999) guidelines for the protection of aquatic life and human health are 0.1 µg/L (100 ng/L) in ambient water and 170 ng/g in sediment (bottom material). Currently (2005), there are no guidelines established by either the USEPA or the CCME for methylmercury in water or bottom material. In this report, all concentrations are discussed in units of nanograms per liter for water and nanograms per gram for bottom material.

Concentrations of filtered and unfiltered total mercury in surface-water, pore-water, and elutriate samples were compared to the USEPA (2003) and CCME (1999) drinking water standards and the CCME (1999) ambient water guideline for the protection of aquatic life and human health. Concentrations of particulate total mercury in surface-water, elutriate, and bottom-material samples were compared to the CCME (1999) sediment guideline for the protection of a quatic life and human health.

Phase 1: Before Spoil-bank Removal and Dredging

Surface-water and bottom-material samples were collected and elutriate samples were processed during phase 1. The maximum concentration of total mercury in filtered surface-water samples collected during phase 1 was 2.40 ng/L, at site 2 (table 2). No concentrations of methylmercury in filtered surface-water samples exceeded the detection limit of the analysis. The maximum concentration of methylmercury in particulate surface water (suspended matter in surface water retained on the filter) was 0.043 ng/g (site 1). There was no analysis of total

mercury in particulate surface water because there was not enough particulate matter in the sample to analyze for both total mercury and methylmercury.

The maximum concentration of total mercury in the bottom-material samples collected during this phase was 53.5 ng/g (site 6). The maximum methylmercury concentration detected in bottom-material samples was 0.074 ng/g (site 6), but concentrations may have been higher in samples with higher detection limits.

Maximum total mercury concentrations in elutriate samples were 0.419 ng/L (site 5) in the filtered and 0.687 ng/g (site 3) in the particulate fractions. Methylmercury was not detected in the filtered elutriate, but a maximum concentration of 0.013 ng/g (site 1) was detected in the particulate samples. All concentrations of total mercury in samples analyzed from this phase were below USEPA (2003) and CCME (1999) guidelines. Mercury concentrations were higher in the bottom-material samples and in the particulate fraction of the surface-water and elutriate samples than in the filtered fraction of the surface-water and elutriate samples.

Table 2. Concentrations of total mercury and methylmercury in samples collected May 15, 2001 (during phase 1, before spoil-bank removal and dredging), from selected sites at the Barataria Preserve, Jean Lafitte National Historical Park and Preserve, Louisiana.

[Laboratory detection limit for filtered analyses is 0.040 nanograms per liter (ng/L). Laboratory detection limits for particulate analyses, in nanograms per gram dry weight (ng/g), are shown in parentheses. Concentrations for filtered samples are in ng/L and for particulate samples are in ng/g. --, no data; LTD, lower than detection limit]

Constituent	Site number (fig. 2)							
	1	2	3	4	5	6	8	
Surface water								
Total mercury, filtered	2.15	2.40	1.19	1.47	0.623	--	--	
Methylmercury, filtered	LTD	LTD	LTD	LTD	LTD	--	--	
Methylmercury, particulate	.043 (.002)	.006 (.002)	.004 (.002)	.011 (.002)	.012 (.002)	--	--	
Bottom material								
Total mercury, particulate	19.4 (3.18)	38.2 (6.41)	42.0 (1.81)	24.8 (1.11)	27.9 (1.24)	53.5 (.737)	37.5 (1.09)	
Total mercury, particulate, field replicate	45.3 (4.24)	--	--	--	15.5 (.648)	53.5 (.258)	28.9 (1.00)	
Methylmercury, particulate	LTD (.203)	LTD (.124)	LTD (.075)	LTD (.126)	LTD (.076)	.074 (.002)	.071 (.004)	
Methylmercury, particulate, field replicate	LTD (.202)	--	--	--	LTD (.088)	LTD (.006)	.102 (.002)	
Elutriates								
Total mercury, filtered	.401	.352	.408	.406	.419	--	--	
Methylmercury, filtered	LTD	LTD	LTD	LTD	LTD	--	--	
Total mercury, particulate	.605 (.254)	.547 (.238)	.687 (.282)	.660 (.285)	.508 (.284)	--	--	
Methylmercury, particulate	.013 (.002)	.012 (.001)	.011 (.001)	.009 (.001)	.007 (.001)	--	--	

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Phase 2: After Spoil-bank Removal, but Before Dredging

Surface-water, pore-water, and bottom-material samples were collected during phase 2. Maximum concentrations of total mercury in surface-water samples collected during phase 2 were 1.98 ng/L in the filtered and 20.7 ng/g in the particulate fractions (table 3); both samples were from site 9. Maximum methylmercury concentrations were 0.043 ng/L (site 7) and 0.709 ng/g (site 9) in the filtered and particulate fractions.

Pore-water samples collected during this phase were analyzed only for the filtered fraction because there was not enough particulate matter to analyze. Maximum total mercury and methylmercury concentrations were 1.55 ng/L (site 12A) and 0.088 ng/L (site 12B). At 3 of the 4 pore-water sampling sites for this phase, concentrations of total mercury were higher in the samples collected at the 2-in. depth than they were in the samples collected at the 14-in. depth.

Maximum concentrations of mercury detected in bottom-material samples collected during this phase were 116 ng/g (site 12B) for total mercury and 4.33 ng/g (site 11A) for methylmercury. The maximum concentrations occurred at marsh sites adjacent to the filled canals, rather than in the canals themselves. At all of the marsh sites sampled during phase 2, total mercury concentrations were higher at the 14-in. depth than at the 2-in. depth. In contrast, methylmercury concentrations were higher at the 2-in. depth at 3 of the 4 marsh sites.

As in phase 1, total mercury concentrations for samples collected during this phase did not exceed USEPA (2003) or CCME (1999) guidelines. The marsh samples indicated some interesting trends. Filtered total mercury concentrations in pore water at 3 of the 4 marsh sites were higher in samples from the 2-in. depth. In contrast, particulate total mercury concentrations in the bottom material were higher in samples from the 14-in. depth, indicating a change in the affinity of mercury to the particulate fraction with increasing depth. Also, total mercury concentrations were higher in bottom-material samples from the marsh sites at the 14-in. depth compared to the 2-in. depth, but methylmercury concentrations were higher at the 2-in. depth. This indicates a higher rate of methylation at shallower depths. The higher methylation rate closer to the surface is consistent with our current understanding of the dominant methylation process whereby sulfate-reducing bacteria near the surface change inorganic mercury into methylmercury (Krabbenhoft and Rickert, 1995).

Phase 3: During Dredging

Phase 3 consisted of surface-water sample collection at sites 6 and 14. At site 14 (the dredge intake), the maximum total mercury concentrations were 0.748 ng/L and 1.49 ng/g in the filtered and particulate fractions (table 4). Methylmercury concentrations were below the detection limit in the filtered fraction, and the maximum concentration detected in the particulate fraction was 0.012 ng/g.

The sample from site 6 was unique in that it was a sample of the slurry output from the dredge and, therefore, did not represent ambient surface water. Unlike other surface-water samples collected during this and previous phases, this sample was too turbid to be analyzed for particulate mercury. In addition to the filtered total mercury and methylmercury analyses, unfiltered total mercury and methylmercury analyses were performed instead of particulate mercury analyses. The filtered total mercury concentration for site 6 was 2.65 ng/L, whereas the filtered methylmercury concentration was below the detection limit.

The unfiltered total mercury concentration was 1,190 ng/L and the unfiltered methylmercury concentration was 0.596 ng/L in this slurry sample. Because the unfiltered concentrations were much higher than the filtered concentrations from the same sample, it is evident that nearly all of the total mercury and methylmercury in this sample was associated with the particulate fraction. The unfiltered total mercury concentration in this sample was much higher than in the other surface-water samples analyzed in this study because (1) the amount of particulate matter in this sample was higher than in the other surface-water samples by a factor of 1,000 or more, and (2) mercury concentrations in the other samples were much higher in particulates than in water. To evaluate the particulate fraction of this slurry sample, the mercury concentration was estimated in terms of bottom material (ng/g) because nearly all of this particulate matter would settle out of the water and into the bottom material after being discharged from the dredge.

The slurry being discharged from a hydraulic dredge, such as the one used in this project, typically ranges in particulate concentration from 50 to 200 g/L, depending on bottom-material and dredge characteristics (Hayes and Schroeder, 1992). To estimate the worst-case mercury concentration in the resulting bottom material, it was assumed that the particulate concentration in our sample was at the low end of the predicted range, 50 g/L. If the unfiltered total mercury concentration (1,190 ng/L) and the unfiltered methylmercury concentration (0.596 ng/L) are divided by the assumed particulate concentration of the slurry (50 g/L), the resulting concentrations are 23.7 ng/g for total mercury and 0.012 ng/g for methylmercury.

At site 14, where the dredge was operating, none of the total mercury concentrations exceeded USEPA (2003) or CCME (1999) guidelines. At site 6, the filtered total mercury concentration was below both sets of guidelines. Also, the unfiltered total mercury concentration expressed as bottom material was below the CCME (1999) guideline for sediment (bottom material). Although the unfiltered total mercury concentration did exceed the CCME (1999) guidelines for drinking water and ambient water, these are not appropriate standards by which to evaluate a water sample with such high particulate concentrations.

10 Total Mercury and Methylmercury at Barataria Preserve

Table 4. Concentrations of total mercury and methylmercury in surface-water samples collected May 14, 2002 (during phase 3, during dredging), from selected sites at the Barataria Preserve, Jean Lafitte National Historical Park and Preserve, Louisiana.

[Laboratory detection limit for filtered and unfiltered analyses is 0.040 nanograms per liter (ng/L). Laboratory detection limits for particulate analyses, in nanograms per gram dry weight (ng/g), are shown in parentheses. Concentrations for filtered and unfiltered samples are in ng/L and for particulate samples are in ng/g. Site 14 was sampled at three locations, A, B, and C, surrounding the operating dredge. --, no data; LTD, lower than detection limit]

Constituent	Site number (fig. 2)			
	6	A	B	C
Total mercury, filtered	2.65	0.700	0.681	0.748
Total mercury, filtered, field replicate	--	--	--	.680
Methylmercury, filtered	LTD	LTD	LTD	LTD
Methylmercury, filtered, field replicate	--	--	--	LTD
Total mercury, particulate	--	1.49 (.037)	.729 (.037)	1.39 (.037)
Total mercury, particulate, field replicate	--	--	--	.946 (.037)
Methylmercury, particulate	--	.012 (.004)	.006 (.004)	.006 (.005)
Methylmercury, particulate, field replicate	--	--	--	.009 (.005)
Total mercury, unfiltered	1,190	--	--	--
Methylmercury, unfiltered	.596	--	--	--

Control Sites

Maximum concentrations of total mercury and methylmercury in pore-water samples from the control sites were 7.67 and 0.354 ng/L, both from site 16A (table 5). Maximum concentrations of total mercury and methylmercury in the bottom material were 118 ng/g (site 15B) and 1.06 ng/g (site 15A).

None of these concentrations exceeded USEPA (2003) or CCME (1999) guidelines. However, concentrations in the samples collected at the control sites contrast with those collected from the marsh sites 10-13, in the area affected by the spoil-bank removal and dredging. The lowest concentration of total mercury in pore water from the control sites (1.43 ng/L, at site 15A [table 5]) was only 0.04 ng/L lower than the maximum value from the marshes adjacent to the two canals (1.47 ng/L, at site 11A [table 3]). Also, the average total mercury concentration in bottom material at the control sites (85.7 ng/g) was higher than the average concentration in bottom material from the marshes adjacent to the two canals in phase 2 (70.1 ng/g).

Implications for Restoration Activities

Based on results from the samples collected for this study, implications for restoration activities are described. During phase 1, no mercury concentrations exceeded USEPA (2003) or CCME (1999) guidelines. The prepared elutriate samples indicated that the slurry created from dredging operations in this area would not increase concentrations of mercury above the guidelines.

Likewise, no concentration of mercury in samples collected during phase 2 exceeded the guidelines. At sites 6 and 8, only bottom material was sampled in both phases 1 and 2. From phase 1 to phase 2, concentrations of total mercury in bottom material decreased at site 6, but increased slightly at site 8. Methylmercury concentrations increased in bottom material at both sites. Total mercury and methylmercury concentrations in bottom material were higher in the marsh adjacent to the filled canals than in the canals themselves. These analyses indicate that, although there was no overall increase in total mercury in the filled canals, there was an increase in methylmercury.

Table 5. Concentrations of total mercury and methylmercury in samples collected May 14, 2002, from two control sites at the Barataria Preserve, Jean Lafitte National Historical Park and Preserve, Louisiana.

[Laboratory detection limit for unfiltered analyses is 0.040 nanograms per liter (ng/L). Laboratory detection limits for particulate analyses, in nanograms per gram dry weight (ng/g), are shown in parentheses. Concentrations for unfiltered samples are in ng/L and for particulate samples are in ng/g. A, sample collected at 2-inch depth; B, sample collected at 14-inch depth; --, no data; LTD, lower than detection limit]

Constituent	Site number (fig. 2)			
	15		16	
	A	B	A	B
Pore water				
Total mercury, unfiltered	1.43	1.76	7.67	1.57
Methylmercury, unfiltered	LTD	LTD	.354	.089
Bottom material				
Total mercury, particulate	70.2 (5.05)	118 (3.79)	71.4 (3.01)	83.2 (2.59)
Total mercury, particulate, laboratory replicate	--	--	--	73.3 (3.85)
Methylmercury, particulate	1.06 (.010)	.125 (.023)	.150 (.030)	.122 (.033)
Methylmercury, particulate, laboratory replicate 1	--	--	--	.092 (.021)
Methylmercury, particulate, laboratory replicate 2	--	--	--	.604 (.038)

The average total mercury concentration at the phase 2 marsh sites (70.1 ng/g) was lower than the average at the control marsh sites (85.7 ng/g). This indicates that the spoil-bank removal between phases 1 and 2 did not increase mercury concentrations in the marshes adjacent to the filled canals, and additional sampling at the marsh sites was unnecessary.

Mercury concentrations for phase 3 sampling in Lake Salvador where the dredge was operating, and filtered mercury concentrations in the slurry generated by the dredge, did not exceed guidelines. Unfiltered mercury concentrations from the slurry, expressed in terms of bottom material, were below the CCME (1999) guideline for mercury in sediment (bottom material). It was necessary to estimate this unfiltered concentration of mercury in terms of bottom material instead of surface water because it was not appropriate to evaluate a water sample so high in suspended material against guidelines for drinking water and ambient water.

Summary

The Barataria Preserve of Jean Lafitte National Historical Park and Preserve is a wetland ecosystem southwest of New Orleans, Louisiana. A study was conducted by the U.S. Geological Survey, in partnership with the National Park Service (NPS), from May 2001 to May 2002 to assess the effects of a coastal restoration project on concentrations of total mercury

and methylmercury in areas within the Preserve. Canals and their spoil banks have affected the local hydrology and have provided a substrate for invasive exotic plants. The project proposed by the NPS called for the restoration of two canals and their spoil banks to the natural marsh level to foster the return of emergent marsh vegetation. To accomplish this, the spoil banks were to be pushed into the canals and the canal openings plugged. Bottom material would be dredged from nearby Lake Salvador and placed on top of the spoil-bank material in one of the canals. The NPS wanted to document potential changes to the wetland environment that might occur during dredging operations, particularly whether the dredging of bottom material and disturbance of spoil banks would cause mercury or methylmercury to be released into the aquatic environment.

The study consisted of three phases to determine (1) background concentrations of total mercury and methylmercury in the area where canals would be modified and the area in Lake Salvador where dredge material would be removed during the project; (2) the total mercury and methylmercury concentrations in and adjacent to the two canals where the spoil banks had been removed, but prior to placement of dredge material from Lake Salvador; and (3) the total mercury and methylmercury concentrations during the dredging operation, at both the intake and output of the dredge. Sixteen sample-collection sites, including two control sites, were selected to monitor potential changes in concentrations of total mercury and methylmercury within the study area and included open water (lake), canals, and peat marsh.

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In this report, analytical results for surface-water, pore-water, bottom-material, and elutriate samples from the 16 sites are presented, and results for the three study phases are discussed. Concentrations of filtered and unfiltered total mercury in surface-water, pore-water, and elutriate samples were compared to established drinking water standards and ambient water guidelines for the protection of aquatic life and human health. Concentrations of particulate total mercury in surface-water, elutriate, and bottom-material samples were compared to sediment guidelines for the protection of aquatic life and human health.

During phase 1, all concentrations of total mercury in samples analyzed were below guidelines. Mercury concentrations were higher in the bottom-material samples and in the particulate fraction of the surface-water and elutriate samples than in the filtered fraction of the surface-water and elutriate samples. The prepared elutriate samples, intended to simulate the dredge material that would be deposited in Middle Access Canal, indicated that the slurry created from dredging operations in this area would not increase concentrations of mercury above the guidelines.

During phase 2 and at the control sites, pore-water and bottom material samples from marsh sites were collected at depths of 2 and 14 inches. Total mercury concentrations for samples collected during phase 2 did not exceed guidelines. Filtered total mercury concentrations in pore water at 3 of the 4 marsh sites were higher in samples from the 2-inch depth. In contrast, particulate total mercury concentrations in the bottom material were higher in samples from the 14-inch depth, indicating a change in the affinity of mercury to the particulate fraction with increasing depth. Also, total mercury concentrations in bottom-material samples from the marsh sites were higher at the 14-inch depth compared to the 2-inch depth, but methylmercury concentrations were higher at the 2-inch depth. This indicates a higher rate of methylation at shallower depths.

During phase 3, none of the total mercury concentrations at the dredge intake exceeded guidelines. At the dredge output, the filtered total mercury concentration was below guidelines, and the total mercury concentration expressed as bottom material was below the guideline for sediment (bottom material). Although the unfiltered total mercury concentration at the dredge output did exceed the guidelines for drinking water and ambient water, these are not appropriate standards by which to evaluate a water sample with such high particulate concentrations.

None of the total mercury concentrations in samples from the two control sites exceeded guidelines. However, concentrations in the samples collected at the control sites contrast with those collected from the marsh sites in the area affected by the spoil-bank removal and dredging. The lowest concentration of total mercury in pore water from the control sites was only 0.04 nanograms per liter lower than the maximum value from the marshes adjacent to the two canals. Also, the average total mercury concentration in bottom material at the control sites was higher than the average concentration in bottom material from the marshes adjacent to the two canals.

From phase 1 to phase 2, concentrations of total mercury in bottom material decreased at site 6 (in Middle Access Canal), but increased slightly at site 8 (in North Keyhole Canal). Methylmercury concentrations increased in bottom material at both sites. Total mercury and methylmercury concentrations in bottom material were higher in samples from the marsh adjacent to the filled canals than from the canals themselves. These analyses indicate that, although there was no overall increase in total mercury in the filled canals, there was an increase in methylmercury.

The average total mercury concentration at the phase 2 marsh sites was lower than the average at the control marsh sites. This indicates that the spoil-bank removal between phases 1 and 2 did not increase mercury concentrations in the marshes adjacent to the filled canals.

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