Bacteriological Water Quality in and Around Lake Pontchartrain Following Hurricanes Katrina and Rita

By Dennis K. Demcheck, Donald M. Stoeckel, Rebecca N. Bushon, David S. Blehert, and Daniel J. Hippe

*The U.S. Geological Survey (USGS), in collaboration with the Louisiana Department of Environmental Quality (LDEQ), monitored sanitary water quality at 22 sites in and around Lake Pontchartrain, La., for 3 consecutive weeks beginning September 13, 2005, following Hurricanes Katrina and Rita. Fecal-indicator bacteria (*Escherichia coli*, enterococci, and fecal coliform) concentrations ranged from the detection limit to 36,000 colony-forming units per 100 mL on north shore streams (September 13–29). A survey of 30 sites in Lake Pontchartrain during the week of October 11–14, 2005, confirmed that there were little widespread, long-term effects on sanitary water quality of Lake Pontchartrain directly caused by Katrina and Rita. Concentrations of fecal-indicator bacteria in tributaries on the north shore of Lake Pontchartrain tended to be high relative to historical data.*

Introduction

Following the Louisiana landfalls of Katrina on August 29 and Rita on September 24, 2005, the local population and the American public were concerned about the effects the hurricanes might have on water quality in Lake Pontchartrain. The lake is a major recreational resource for the region and an important fishery. Contamination carried by the storm surge—along with runoff and water pumped from flooded areas of New Orleans—was considered a serious threat to the water body. The USGS, in collaboration with the LDEQ, monitored the sanitary quality of water at 22 sites in and around Lake Pontchartrain, La., for 3 consecutive weeks from September 13 to 29, 2005 (fig. 1). A subsequent multiple-agency survey of 30 sites within Lake Pontchartrain was undertaken by the U.S. Environmental Protection Agency (EPA), the USGS, and the National Oceanic and Atmospheric Administration during the week of October 11–14, 2005, to evaluate the effects of the hurricanes and overall levels of fecal contamination on the water quality of the lake (see Heitmuller and Perez, this volume). In

addition, the EPA monitored fecal-indicator concentrations at a variety of sites in New Orleans, surrounding areas, and the Mississippi River between September 3 and October 22, 2005 (U.S. Environmental Protection Agency, 2006). This article describes fecal-indicator bacteria concentration results collected by USGS in the context of other existing data.

Although called Lake Pontchartrain, the water body is a shallow estuarine bay with an average depth of only 11 ft (3.35 m) (Kindinger and others, 2002). The lake has two connections with the Gulf of Mexico: Chef Menteur Pass and The Rigolets (fig. 1). New Orleans is located on the south shore of the lake, and the east and north shores are mostly residential. Historically, the north shore was primarily forested with a narrow, fringing brackish marsh; dairies and forestry located farther inland have been the main industries. Populations in communities on the north shores with extensive suburban areas, such as Covington and Slidell, La., have been rapidly expanding over the last 30 years (Demcheck and others, 1996); however, much of the western shore remains marshy and sparsely populated.

After Katrina, there were widely held concerns about the effects of contaminated flood water being pumped out of New Orleans and into Lake Pontchartrain. It was assumed that there would be a massive influx of sewage, among other contaminants, into the lake. In response, the LDEQ coordinated with the USGS to assess and monitor water quality in Lake Pontchartrain and adjacent water bodies at 22 sites. Ten of the 22 sites had historical LDEQ data, so results from the September 13–29, 2005, sampling could be compared to previous conditions at those 10 sites in the lake. The 22 sites included passes, north shore tributaries, south shore canals, a north-south transect across the lake, and an east-west transect about 0.5 mi (0.8 km) off of the southern shore at points associated with various south shore canals (fig. 1). Thus, the sites represented inputs into the lake, conditions within various regions of the lake, and outputs into the Gulf of Mexico.

Results

Fecal-indicator bacteria (*Escherichia coli*, enterococci, and fecal coliform) concentrations in samples collected from September 13 to 29 ranged from the detection limit to 36,000 colony-forming units (cfu) or most-probable numbers (MPN) per 100 mL of water. Reporting units (cfu or MPN) varied based on the nature of the measurement tests. Fecal-indicator bacteria concentrations in the lake following Katrina generally were well below applicable water-quality criteria; those measurements that showed high concentrations relative to the criteria did not support the assumption that pumpage from New Orleans would lead to widespread contamination of the lake. This observation may be partially explained by the combined effects of dilution and the various processes that

Figure 1. Locations of sampling sites used by the U.S. Geological Survey during a 3-week survey from September 13 to 29, 2005.

occurred while flood water sat in New Orleans prior to being pumped out to the lake via canals. Elevated concentrations, where observed, did not extend far into the lake (Stoeckel and others, 2005). The subsequent multiple-agency survey of 30 additional sites in Lake Pontchartrain the week of October 11–14 confirmed that, overall, fecal-indicator concentrations in the lake remained low in the weeks following Rita (see Heitmuller and Perez, this volume).

The results of the September 13–29, 2005, USGS intensive bacteriological analyses conducted at 22 sites are described by Stoeckel and others (2005). The most significant findings from the USGS data collection effort follow:

1. During the first week of sampling, the highest fecal coliform concentration was 2,200 cfu/100 mL in the pumpage plume from the Metairie Outfall Canal (popularly known as the 17th Street Canal). Although this concentration is over five times higher than the 400 cfu/100 mL Louisiana standard for recreational water quality, it is much lower than what was expected based on preliminary EPA results in flood waters that ranged to nearly 100,000 *E. coli* cfu/100 mL (U.S. Environmental Protection Agency, 2006). Personnel from USGS were prepared to quantify fecal-indicator bacteria concentrations 1,000 times higher than were observed. Despite the high concentration measured in the pumpage plume, fecal coliform concentrations at a point less than 0.5 mi (0.8 km) offshore from the outlet of the 17th Street Canal were within Louisiana's standards for recreational water quality. It was apparent that incomplete mixing of flood and lake waters and dilution, possibly augmented by settling and bacterial die-off during holding and pumping to the lake, resulted in maintenance of low fecal-indicator bacteria concentrations in the lake relative to Louisiana water-quality criteria.
2. Fecal-indicator bacteria concentrations at the three sites in a north-south transect along the Lake Pontchartrain Causeway were very low during all 3 weeks of sampling after Katrina and after Rita. The hurricanes did not substantially increase fecal-indicator bacteria concentrations in the lake as a whole. Sites where concentrations were high relative to water-quality criteria generally were limited to sites near the northern and southern shores of the lake (table 1).
3. Fecal bacteria concentrations were higher along the north shore of Lake Pontchartrain after Rita than after Katrina. For example, the maximum fecal coliform concentration on the north shore stream Liberty Bayou was 1,400 cfu/100 mL on September 13 but rose to 7,300 cfu/100 mL on September 27 (Rita landed on September 24). There are several factors that could account for this pattern, which was observed at many of the north shore sites. First, post-Rita sampling began only 4 days after storm passage, compared to 15 days after storm passage for post-Katrina sampling. Second, precipitation during Rita flushed both Katrina-deposited organic material and new organic material into the north shore tributaries. A third potential factor is that, whereas the population of New Orleans (south of Lake Pontchartrain) was still almost completely evacuated during the 3 weeks of sampling, the populations in the parishes along the north shore of Lake Pontchartrain were increased by New Orleans evacuees. This increase resulted in additional stress on damaged or overwhelmed sewage treatment facilities.
4. At sites in five of six tributaries on the north shore of Lake Pontchartrain, fecal coliform concentrations following Katrina and Rita tended to be higher than the median

Table 1. Pattern of fecal-indicator concentrations measured in and around Lake Pontchartrain, La., in September 2005 and relation to standards and criteria.

[EPA, U.S. Environmental Protection Agency; LDEQ, Louisiana Department of Environmental Quality; cfu, colony-forming unit]

Class	*E. coli* criterion EPA fresh water infrequent full-body contact 575 cfu/100 mL			Enterococci criterion EPA fresh or marine water infrequent full-body contact 151 (fresh) or 501 (marine) cfu/100 mL			Fecal coliform standard LDEQ all water types and designated uses 400 cfu/100 mL		
	Meet	Exceed	Unclear*	Meet	Exceed	Unclear*	Meet	Exceed	Unclear*
South shore canals	4	0	0	4	2	3	5	4	0
East-west lake transect	not applicable (marine)			18	0	1	17	2	0
North-south lake transect	not applicable (marine)			10	0	0	10	0	0
North shore tributaries	26	2	2	19	7	5	17	9	0
Passes	not applicable (marine)			6	1	0	7	0	0

* Classification of a sample into Meet or Exceed category was unclear because either (1) multiple observations from the sample resulted in different classifications or (2) the 95% confidence interval around at least one observation from the sample included the value of the standard or criterion.

values of historical samples collected by LDEQ; however, most observations were within the 95th percentile of the historical observations. At the Tangipahoa River site, the distribution of fecal coliform concentrations was similar to historical observations. Thus, north shore tributaries had contamination that, while not unprecedented, was high compared to the range of historical conditions.

5. At four sites (Suburban Canal, Inner Harbor Navigation Canal (popularly known as the Industrial Canal), The Rigolets, and the middle of Lake Pontchartrain), fecal coliform concentration distributions observed after the hurricanes were similar to distributions in historical data. Posthurricane concentrations at one south shore canal, Duncan Canal, however, were higher than the median of prior observations.

Evaluation of combined data collected by multiple agencies contributed to better understanding of fecal contamination dynamics in the Lake Pontchartrain basin following Katrina and Rita. For example, comparison of bacteriological data collected by the EPA within the flooded areas of New Orleans (U.S. Environmental Protection Agency, 2006) against data collected at USGS sites (Stoeckel and others, 2005) was used to understand the extent of concentration reductions as flood water was pumped into Lake Pontchartrain (fig. 2). Concentrations of *E. coli* bacteria measured in New Orleans flood water were as high as 100 times the EPA criterion for infrequent full-body contact recreation (criterion is 575 cfu/100 mL; EPA observed 60,000 *E. coli* cfu/100 mL in Orleans Parish on October 5, 2005), and the median value among EPA floodwater data was 900 *E. coli* cfu/100 mL. Nevertheless, concentrations measured by the USGS along the south shore of Lake Pontchartrain never exceeded 63 *E. coli* cfu/100 mL (measured at Bayou LaBranche), and offshore concentrations in Lake Pontchartrain never exceeded 10 *E. coli* cfu/100 mL. The reduction in concentration as water flowed along canals to pump stations and was discharged into Lake Pontchartrain can be seen in figure 2.

A joint EPA, USGS, and National Oceanic and Atmospheric Administration study of fecal-indicator bacteria from 30 sites within Lake Pontchartrain was conducted during October 11–14, 2005. The most significant finding was that concentrations were never higher than 10 cfu/100 mL for fecal coliforms or 1 cfu/100 mL for enterococci. Although this survey was done more than 18 days after Rita, the results confirmed that there was little, if any, widespread, long-term effect on sanitary water quality of Lake Pontchartrain directly caused by Katrina and Rita.

In addition to fecal-indicator bacteria measurements, water samples were examined at selected sites for potentially pathogenic bacteria of the genus *Vibrio*, including *V. cholerae*, *V. parahaemolyticus*, and *V. vulnificus*. While greater bacterial diversity was observed in samples collected after Rita, pandemic strains of *V. cholerae* or *V. parahaemolyticus* were not found, and *V. parahaemolyticus* strains carrying the

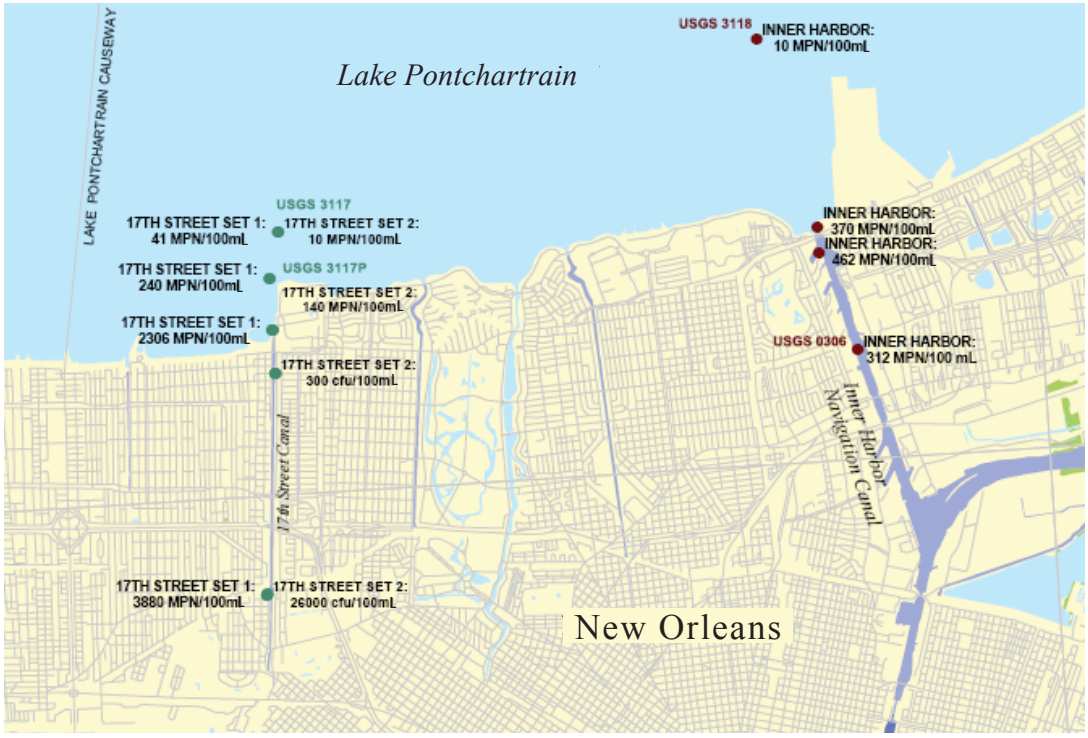

Figure 2. *Escherichia coli* data collected by the U.S. Geological Survey and the U.S. Environmental Protection Agency in and around New Orleans, La., during the period September 13–29, 2005, that depict relative concentrations in pumped flood water and lake-receiving water. (MPN = most probable number; cfu = colony forming unit.)

virulence gene were not present at elevated levels at any of the sample sites. *Vibrio vulnificus* was isolated from a water sample collected from the plume in Lake Pontchartrain just offshore from the 17th Street Canal on September 29, 2005. Quantitative measurements for *V. vulnificus* were done on 12 samples from the lower reaches of north shore tributaries and the three passes (Pass Manchac, The Rigolets, and Chef Menteur Pass). Among these, *V. vulnificus* was present at higher levels (2,200–8,000 cfu/100 mL) in five of eight samples collected among four north shore tributaries than is generally observed in U.S. Gulf Coast waters (calculated from dePaola and others, 1994). *Vibrio vulnificus* tended to be at lower concentrations than typical for Gulf Coast waters in samples from Chef Menteur Pass and The Rigolets (locations shown in fig. 1). When potentially pathogenic vibrios were detected from Lake Pontchartrain and adjacent water bodies, concentrations of fecal-indicator bacteria tended to exceed water-quality standards. This relationship was documented at Bayous Liberty and Bonfouca on September 27 (after Rita). These vibrios may have increased the health risk associated with area waters. Twenty-two people, including five fatalities, contracted vibrio-related diseases after the two hurricanes (Centers for Disease Control and Prevention, 2005).

Discussion and Conclusions

Though the damage caused to New Orleans and surrounding communities by Katrina and Rita was devastating to the collective psyche, infrastructure, and the economy of the area, the effects of fecal contamination on sanitary water quality of Lake Pontchartrain appeared to be localized. Evacuation of New Orleans during the two hurricanes left relatively few sources of human fecal contamination along the south shore of Lake Pontchartrain during the study period. Substantial numbers of New Orleans residents, however, found temporary housing in north shore communities, which also had experienced severe damage. Many wastewater treatment plants fringing Lake Pontchartrain were inoperable during the weeks following the hurricanes. Therefore, it is expected that partially or entirely untreated sanitary waste was released into the Lake Pontchartrain basin, especially along the north and east shores. These releases may have been partially responsible for the elevated fecal-indicator concentrations observed in north shore tributaries.

Concentrations of fecal indicators and, by association, fecal pathogens in New Orleans flood waters declined as they were pumped to Lake Pontchartrain. Possible mechanisms for this decline include dilution, natural die-off, settling, and solar irradiation as the waters were pooled in New Orleans and the stress of jet aeration before discharge into the lake. Despite the inputs of substantial fecal contamination from New Orleans flood water and north shore tributaries, evidence collected (fecal-indicator bacteria concentrations and distribution of potentially pathogenic bacteria of the genus *Vibrio*) indicated that Katrina and Rita did not substantially change the overall sanitary water quality of Lake Pontchartrain.

Acknowledgments

Angelo dePaola and Jessica Nordstrom, U.S. Food and Drug Administration, Gulf Coast Seafood Laboratory, analyzed for vibrio toxin genes and concentrations of *V. vulnificus* and *V. parahaemolyticus* in support of this research. Brenda Berlowski, USGS National Wildlife Health Center, provided technical assistance for vibrio analyses. The LDEQ provided historical fecal coliform concentration data, and EPA personnel helped compile *E. coli* concentration data from New Orleans flood water.

References

Centers for Disease Control and Prevention, 2005, Vibrio illnesses after Hurricane Katrina—multiple states, August–September 2005: Morbidity and Mortality Weekly Report, v. 54, no. 37, p. 928–931, *http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5437a5.htm*, accessed May 11, 2006.

Demcheck, D.K., 1996, Analysis of selected water-quality data for surface water in St. Tammany Parish, Louisiana, April-August 1995: U.S. Geological Survey Open-File Report 96-345, 58 p.

dePaola, A., Capers, G.M., and Alexander, D., 1994, Densities of *Vibrio vulnificus* in the intestines of fish from the U.S. Gulf Coast: Applied and Environmental Microbiology, v. 60, p. 984–988.

Kindinger, J., Penland, S., and Beall, A., 2002, Environmental atlas of Lake Pontchartrain basin: U.S. Geological Survey Open-File Report 02-206, *http://pubs.usgs.gov/of/2002/of02-206/*, accessed May 11, 2006.

Myers, D.N., and Wilde, F.D., eds., 2003, Biological indicators (3d ed.): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A7, 163 p., *http://pubs.water.usgs.gov/twri9A7/*, accessed July 5, 2006.

Stoeckel, D.M., Bushon, R.N., Demcheck, D.K., Skrobialowski, S.C., Kephart, C.M., Bertke, E.E., Mailot, B.E., Mize, S.V., and Fendick, R.B., Jr., 2005, Bacteriological water quality in the Lake Pontchartrain basin, Louisiana, following Hurricanes Katrina and Rita, September 2005: U.S. Geological Survey Data Series 143, 21 p.

U.S. Environmental Protection Agency, 2006, Response to 2005 hurricanes: Enviromapper-served data, *http://www.epa.gov/enviro/katrina/emkatrina.html*, accessed May 11, 2006.

Veley, R.J., Francy, D.S., and Darner, R.A., 1998, How do we determine when the beaches are safe for swimming?: U.S. Geological Survey Fact Sheet FS-112-98.

Contact Information

Dennis K. Demcheck, Supervising Hydrologist (*ddemchec@usgs.gov*)
U.S. Department of the Interior
U.S. Geological Survey
Louisiana Water Science Center
Baton Rouge, LA 70816

Donald M. Stoeckel, Hydrologist (*stoeckel@usgs.gov*); and Rebecca N. Bushon, Hydrologist (*rnbushon@usgs.gov*)
U.S. Department of the Interior
U.S. Geological Survey
Ohio Water Microbiology Laboratory
Columbus, OH 43229

David S. Blehert, Microbiologist (*dblehert@usgs.gov*)
U.S. Department of the Interior
U.S. Geological Survey
National Wildlife Health Center
Madison, WI 53711

Daniel J. Hippe, Water Quality Specialist (*djhippe@usgs.gov*)
U.S. Department of the Interior
U.S. Geological Survey
Water Resources Discipline
Eastern Region
Reston, VA 20192

Fecal Indicator

What are fecal-indicator bacteria?

Fecal-indicator bacteria are used to determine the risk of contracting waterborne disease from fecal-contaminated recreational waters (Veley and others, 1998). Although they do not typically cause diseases, their presence can indicate the possible presence of several waterborne disease-causing organisms. Groups include the following:

- Fecal coliform bacteria: a group of coliform bacteria generally originating from the wastes of warm-blooded animals, including those of humans (Myers and Wilde, 2003). It includes the *Escherichia coli* (*E. coli*) group. At least one member of the fecal coliform group, however, has nonfecal sources.

- *E. coli* and enterococci: the preferred indicators used for assessing the microbiological quality of recreational waters because they are generally superior predictors of swimming-associated gastroenteritis. The presence of *E. coli* in recreational waters is direct evidence that fecal contamination has occurred.

For additional information on fecal-indicator bacteria and associated water-chemistry results from this effort, including comparisons to Louisiana Department of Environmental Quality historical data, refer to Stoeckel and others (2005). This report is available online at *http://pubs.usgs.gov/ds/2005/143/*.

CDC/ Vibrio Pathogens

In the aftermath of Hurricane Katrina, the Centers for Disease Control and Prevention (CDC) issued a report that indicated increased rates of illness caused by pathogens of the genus Vibrio after the storm (Centers for Disease Control and Prevention, 2005). Most of these illnesses were wound infections caused by *V. vulnificus* and *V. parahaemolyticus*. Wound infections by these pathogens can be fatal and are associated with severe symptoms including fever, decreased blood pressure induced by septic shock, and blood-tinged skin blisters. Wound infections are caused by noncholeragenic vibrios, in other words, those that do not cause the disease *cholera*. Cholera is associated with specific types of *V. cholera* and causes severe gastroenteritis. Pandemic choleragenic and noncholeragenic vibrios are capable of causing disease that spreads from person to person. Nonpandemic vibrios are spread by environmental factors, such as consumption of contaminated seafood.