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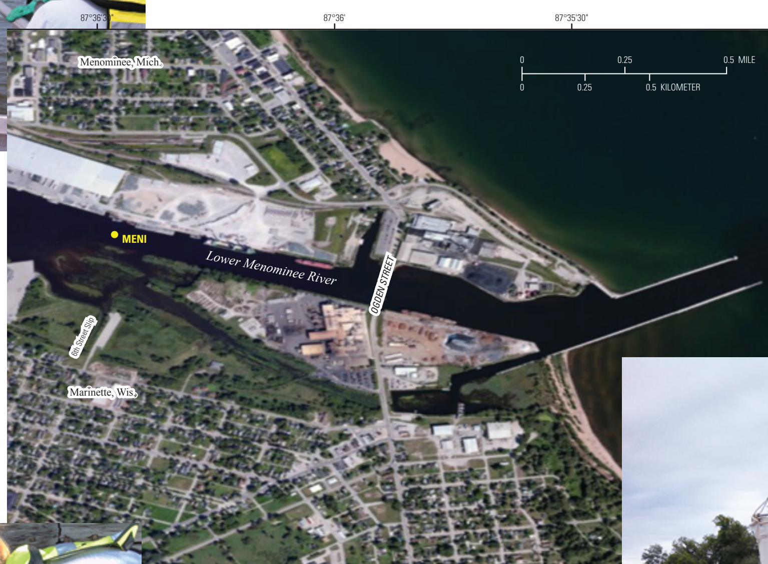
Benthos and Plankton Community Data for Selected Rivers and Harbors Along the Western Lake Michigan Shoreline, 2014



Data Series 1000

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Benthos and Plankton Community Data for Selected Rivers and Harbors Along the Western Lake Michigan Shoreline, 2014

By Barbara C. Scudder Eikenberry, Daniel J. Burns, Hayley A. Templar,
Amanda H. Bell, and Kassidy T. Mapel

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Contents

Figures

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
milliliter (mL)	0.03381	ounce, fluid (fl. oz)
liter (L)	0.2642	gallon (gal)
	Flow rate	
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32.$$

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Supplemental Information

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Abbreviations

AOC	Area of Concern
BUI	Beneficial Use Impairment
EPA	U.S. Environmental Protection Agency
GLNPO	Great Lakes National Program Office
HD	Hester-Dendy [artificial substrate sampler]
LRSI	Lake Superior Research Institute—University of Wisconsin-Superior
non-AOC	non-Area of Concern comparison site
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
QA–QC	quality assurance and quality control
USGS	U.S. Geological Survey
VOC	volatile organic compound
WDNR	Wisconsin Department of Natural Resources
WSLH	Wisconsin State Laboratory of Hygiene

Benthos and Plankton Community Data for Selected Rivers and Harbors Along the Western Lake Michigan Shoreline, 2014

By Barbara C. Scudder Eikenberry, Daniel J. Burns, Hayley A. Templar, Amanda H. Bell, and Kassidy T. Mapel

Abstract

Benthos (benthic invertebrates) and plankton (zooplankton and phytoplankton) communities were sampled in 2014 at 10 Wisconsin rivers and harbors, including 4 sites in Great Lakes Areas of Concern and 6 less degraded comparison sites with similar physical and chemical characteristics, including climate, latitude, geology, and land use. Previous U.S. Geological Survey sampling was completed in 2012, but because of ongoing sediment remediation at three of the Areas of Concern (AOCs) and unusually hot and dry conditions in many areas during 2012, additional sampling was added in 2014. Comparable sampling methods were used in 2012 and 2014. Benthos were collected by using Hester-Dendy artificial substrate samplers and composite Ponar grab samples of bottom sediment; zooplankton were collected by using tows from depth to the surface with a 63-micrometer mesh plankton net; phytoplankton were collected by using whole water samples composited from set depth intervals. This report describes the study areas and field sampling methods for 2014, and it presents data on taxonomic identification and abundance of benthos and plankton that can serve as a basis for evaluation of related Beneficial Use Impairments (BUIs) at the AOCs. Physical and chemical data were sampled concurrently (specific conductance, temperature, pH, dissolved oxygen, chlorophyll *a*, total and volatile suspended solids in water samples; particle size and volatile-on-ignition of sediment in benthic grab samples). The results of field quality assurance-quality control are also presented.

Introduction

In 2012 and 2014, the U.S. Geological Survey (USGS), in cooperation with the Wisconsin Department of Natural Resources (WDNR) and the U.S. Environmental Protection Agency (EPA), collected benthos (bottom-dwelling invertebrates) and plankton (zooplankton and phytoplankton) at 10 sites in rivers and harbors along Wisconsin's Lake Michigan shoreline. Four sites were in designated Areas of Concern (AOCs), and six sites were less degraded comparison sites with similar physical and chemical characteristics but were not designated AOCs (referred to hereafter as non-AOCs). Each AOC is designated or "listed" because it has at least 1 of 14 defined Beneficial Use Impairments (BUIs). A BUI is an adverse change or condition of a Great Lakes area that causes impairment in the area's chemical, physical, or biological integrity, such as degradation of benthos or plankton populations, that limits the area's ability to support aquatic life.

The overall goal of the study was to inform the decision-making process with regard to removal of the BUI for degradation of benthos and the BUI for degradation of plankton populations. The purpose of this report is to describe the study areas and field sampling methods for 2014 and to present data on taxonomic identification and abundance of benthos and plankton that can serve as a basis for evaluation of related BUIs at the AOCs. Benthos were collected by using a grab sampler and artificial substrate samplers; plankton were collected with a tow net for zooplankton and a vertical water sampler for phytoplankton. Physical and chemical data were sampled concurrently (specific conductance, temperature, pH, dissolved oxygen, chlorophyll *a*, total and volatile suspended solids in water samples; particle size and volatile-on-ignition of sediment in benthic grab samples), and the results of field quality assurance and quality control (QA–QC) are also presented. Methods and data for 2012 were published previously (Scudder Eikenberry and others, 2014).

Site Descriptions

In the late 1980s, 43 sites around the Great Lakes were designated as AOCs by the United States and Canada because of pollution (International Joint Commission, United States and Canada, 1987). Sites in 4 of these 43 AOCs and 6 non-AOC comparison sites were selected for this study (table 1, fig. 1). The 4 AOC sites are the Lower Menominee River, Lower Green Bay and Fox River, Sheboygan River, and Milwaukee Estuary; the 6 non-AOC sites are the Escanaba River, Oconto River, Ahnapee River, Kewaunee River,

Table 1. U.S. Geological Survey sampling locations at Wisconsin's Lake Michigan Areas of Concern (AOCs) and non-AOC comparison sites in Wisconsin and Michigan, including station identification number, latitude, longitude, drainage area, and discharge.

[SWIMS, Wisconsin Department of Natural Resources Surface Water Integrated Monitoring System; km^2, square kilometer; ft^3/s, cubic feet per second; AOCs, Areas of Concern; NA, not available; Non-AOCs, Non-Areas of Concern]

Map number (fig. 1)	Site name	Site abbre-viation	SWIMS station number	Latitude (decimal degrees)	Longitude (decimal degrees)	Drainage area (km^2)	Annual mean discharge,[1] 2012 (ft^3/s)	Annual mean discharge,[1] 2014 (ft^3/s)	Annual mean discharge,[1] historical (ft^3/s)	Period of discharge record[1]	Map number of comparison site
					AOCs						
1	Lower Menominee River	MENI	10037445	45.09810	-87.60772	10,490	1,983	3,419	3,190	1945–2014	5, 6
2	Lower Green Bay and Fox River										
2a	Lower Green Bay	GREE	10037530	44.57751	-87.98600	16,584	NA	NA	NA	NA	NA
	Green Bay Historical Site 8	GB08	053477	44.54861	-87.94861	16,584	NA	NA	NA	NA	NA
	Green Bay Historical Site 16	GB16	10042335	44.55972	-87.95972	16,584	NA	NA	NA	NA	NA
	Green Bay Historical Site 17	GB17	10042339	44.57222	-87.93889	16,584	NA	NA	NA	NA	NA
	Green Bay Historical Site 3-1	GB03	053243	44.56611	-87.99158	16,584	NA	NA	NA	NA	NA
	Green Bay Historical Site 5	GB05	053273	44.54444	-87.99444	16,584	NA	NA	NA	NA	NA
2b	Fox River near Allouez	FOXR	10037435	44.49499	-88.02424	16,178	4,346	5,397	4,722	1989–2014	7, 8
3	Sheboygan River	SHEB	10037451	43.74887	-87.70352	1,043	239	379	273	1916–2014	8, 9
4	Milwaukee Estuary										
4a	Milwaukee River	MILR	10037448	43.04789	-87.91269	1,779	438	670	453	1914–2014	9, 10
4b	Menomonee River	MENO	10037446	43.03220	-87.92156	381	98.3	121	155	2009–14	9, 10
4c	Milwaukee Harbor	MILH	10037447	43.02501	-87.89722	2,193	562	821	750	1994–2014	NA
					Non-AOC comparison sites						
5	Escanaba River, Michigan	ESCA	10037431	45.77845	-87.06325	2,393	NA	NA	829	1988–90	1
6	Oconto River	OCON	10037449	44.89198	-87.83678	2,502	541	809	604	1989–2014	1, 2b
7	Ahnapee River	AHNA	10037430	44.60979	-87.43484	274	NA	NA	NA	NA	2b
8	Kewaunee River	KEWA	10037436	44.46073	-87.50205	354	58.1	93.4	82.3	1964–2014	2b, 3
9	Manitowoc River	MANI	10037444	44.09190	-87.66183	1,341	352	474	320	1972–2014	3, 4a, 4b
10	Root River	ROOT	10037450	42.72866	-87.78827	514	86.8	130	159	1963–2014	4a, 4b

[1]Based on the nearest U.S. Geological Survey streamgage.

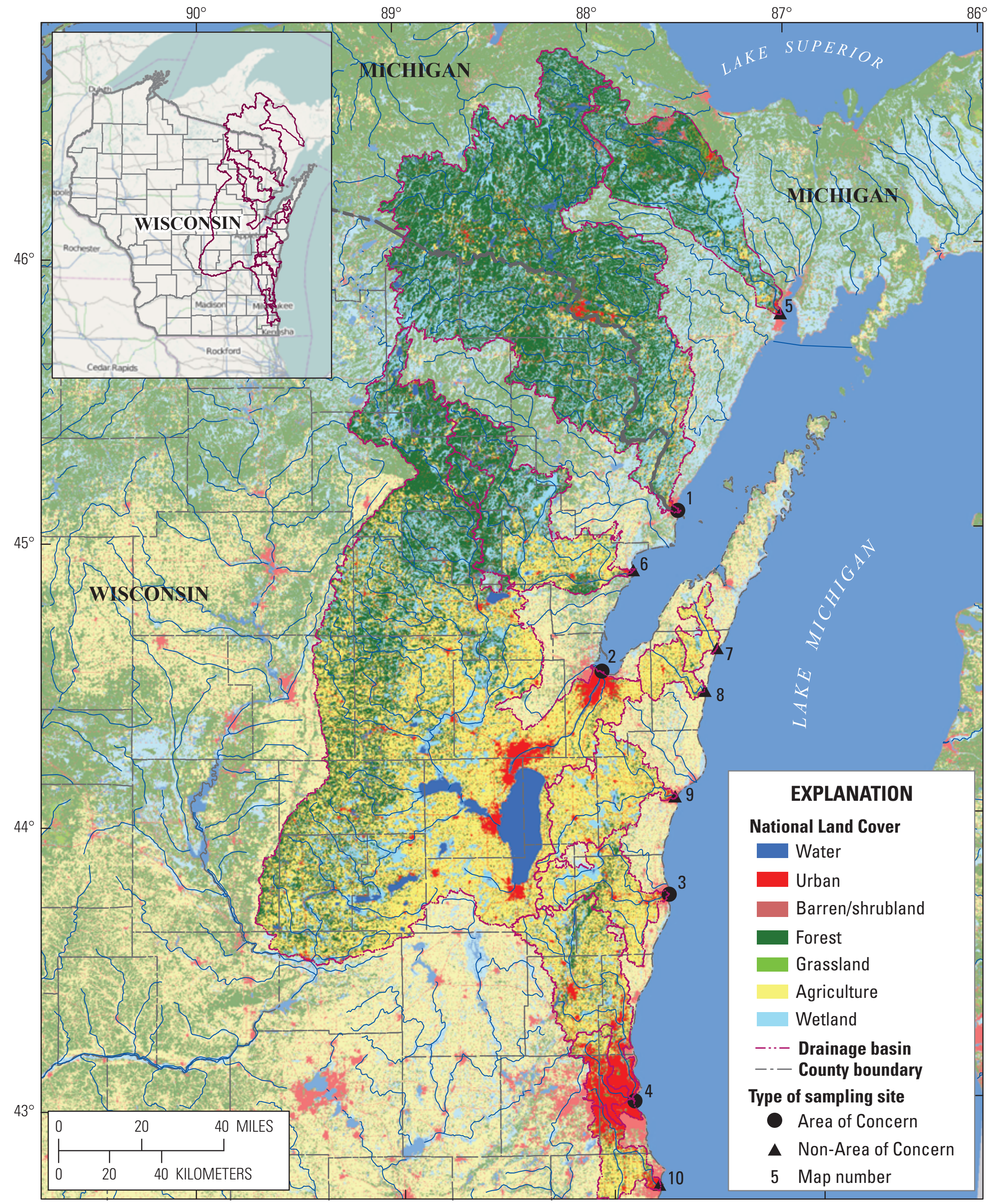

Figure 1. 10 sites where samples were collected for benthos and plankton communities in 2014 along Wisconsin's Lake Michigan shoreline, and land cover classes. See table 1 for site names and sampling location information.

Manitowoc River, and Root River. The term “site” refers to a geographic area being sampled (for example, the Lower Green Bay and Fox River AOC). The term “location” refers to the specific area of sampling within a site. Detailed site information including land use-land cover is provided in Scudder Eikenberry and others (2014).

Lower Menominee River Area of Concern

The Lower Menominee River AOC along the Wisconsin-Michigan border is the northernmost AOC in the study (figs. 1 and 2, table 1), and it has a drainage area of 10,490 square kilometers (km^2). It was designated an AOC because of sediment contamination with arsenic, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs, or coal tars), paint sludge, and heavy metals including cadmium, chromium, copper, lead, mercury, nickel, and zinc (Wisconsin Department of Natural Resources and Michigan Department of Environmental Quality, 2011). This AOC has a BUI for benthos but not for plankton. Contaminated sediment removal began in 2009 and continued through 2014 (U.S. Environmental Protection Agency, 2013b; Wisconsin Department of Natural Resources, 2015a). The sampling location (MENI) for benthos and plankton was the same as in 2012, downstream of the dredging area in the main channel and slightly upstream of the 6th Street Slip. In 2014, to avoid issues encountered with ongoing dredging operations, the artificial substrate samplers (Hester-Dendy or HD samplers) were deployed less than 0.4 kilometer (km) downstream of the dredge site and the 2012 HD sampler site, off the right bank of the main channel. The Escanaba and Oconto Rivers were used as comparable river systems for the Lower Menominee River because of similar climate (cooler temperatures and greater snowfall than the more southern AOCs) and geology.

Lower Green Bay and Fox River Area of Concern

The Lower Green Bay and Fox River AOC (fig. 3), with a drainage area of 16,584 km^2, is the largest system in this study. It is located near the confluence of the Fox River with Green Bay. The bay is different from any other system in the Great Lakes because of its size and unique circulation patterns. The Fox River historically had discharges of contaminants, primarily PCBs that were noted as the main cause of AOC designation; nutrient enrichment is also a problem (U.S. Environmental Protection Agency, 2013a; Wisconsin Department of Natural Resources, 2014a). Extensive remediation efforts including removal of contaminated sediment are underway and will continue through at least 2017. Benthos and plankton samples were collected at two locations that this study also sampled in 2012: in Green Bay, just southeast of Dead Horse Bay (GREE) (fig. 3, table 1), and in the Fox River near Allouez, Wisconsin, downstream of State Highway 172 at the railroad bridge (FOXR) (fig. 4, table 1). In 2014, benthos grab samples were collected at five additional locations (GB03, GB05, GB08, GB16, and GB17) of historical benthos sampling in Green Bay. Despite smaller drainage areas, the Ahnapee River and Kewaunee River were chosen as sites of comparison to the Fox River on the basis of similar climate, latitude, and geology. Green Bay, however, could not be compared directly to any other non-AOC system in the Great Lakes because of its unique characteristics.

Sheboygan River Area of Concern

The Sheboygan River (fig. 5, table 1), with a drainage area of 1,043 km^2, is the smallest of the AOC watersheds. The AOC was designated because of concerns about sediment contamination from PCBs, PAHs, volatile organic compounds (VOCs), and heavy metals (Wisconsin Department of Natural Resources, 1995, 2012). Sediment dredging for remediation was completed in June 2013 (Wisconsin Department of Natural Resources, 2013, 2014c). The USGS sampling location (SHEB) was downstream of the dredged areas and near the mouth of the river below the 8th Street Bridge. The non-AOC sites used as comparison sites for the Sheboygan River AOC are the Kewaunee and Manitowoc Rivers because of similar climate, latitude, geology, and land use. The Manitowoc River and Sheboygan River also have similar drainage areas.

Milwaukee Estuary Area of Concern

At the Milwaukee Estuary AOC, three rivers converge to form the Milwaukee Inner Harbor before flowing into Lake Michigan (fig. 6). The Milwaukee River (fig. 7, table 1) is the largest river, with a drainage area of 1,779 km^2, and the sampling site (MILR) was about 0.15 km upstream of Knapp Street. The Menomonee River (fig. 8, table 1) has a drainage area of 381 $km^{2,}$ and the sampling site (MENO) was immediately downstream of the North-South Freeway. The Kinnickinnic River was not sampled because of its small size (less than 65 km^2) and generally shallow depth, which posed problems with sampling logistics. The Milwaukee Harbor sampling site (MILH) was adjacent to the USGS streamgage at Jones Island (fig. 9, table 1). Contaminants of concern in the Milwaukee Estuary AOC are mainly PCBs, PAHs, pesticides, and heavy metals, such as cadmium, copper, and zinc (Wisconsin Department of Natural Resources, 1994, 2014b). Sediment remediation is in progress. The original AOC boundary established in the late 1980s was expanded in 2008 to include upstream reaches with known sources of contamination (U.S. Environmental Protection Agency, 2013c). The non-AOC comparison sites for the Milwaukee and Menomonee Rivers were the Manitowoc and Root Rivers because of similar climate, geology, and land use. The Milwaukee River and Manitowoc River are similar in drainage area, and the Menomonee River and Root River are similar in drainage area.

Figure 2. The U.S. Geological Survey sampling location for benthos and plankton communities in the Lower Menominee River Area of Concern, between Menominee, Michigan, and Marinette, Wisconsin.

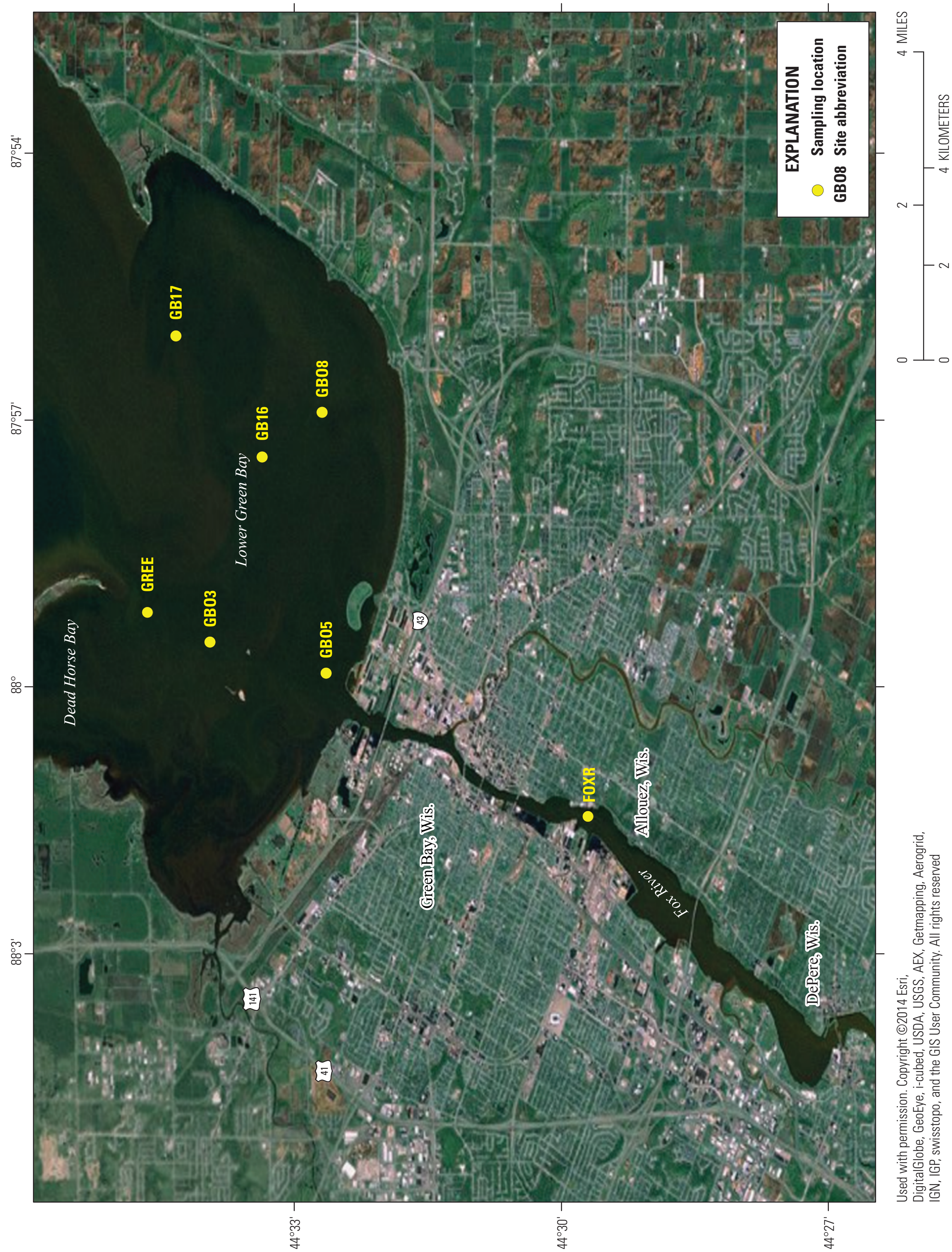

Figure 3. U.S. Geological Survey sampling locations for benthos and plankton communities in the Lower Green Bay and Fox River, Wisconsin, Area of Concern.

Figure 4. The U.S. Geological Survey sampling location for benthos and plankton communities in the Fox River near Allouez, Wisconsin, within the Lower Green Bay and Fox River, Wisconsin, Area of Concern.

Figure 5. U.S. Geological Survey sampling location for benthos and plankton communities in the Sheboygan River, Wisconsin, Area of Concern.

Figure 6. U.S. Geological Survey sampling locations in the Milwaukee River, Menomonee River, and Milwaukee Harbor for benthos and plankton communities in the Milwaukee Estuary, Wisconsin, Area of Concern.

Figure 7. The U.S. Geological Survey sampling location for benthos and plankton communities in the Milwaukee River within the Milwaukee Estuary, Wisconsin, Area of Concern.

Figure 8. The U.S. Geological Survey sampling location for benthos and plankton communities in the Menomonee River within the Milwaukee Estuary, Wisconsin, Area of Concern.

Figure 9. The U.S. Geological Survey sampling location for benthos and plankton communities in the Milwaukee Harbor within the Milwaukee Estuary, Wisconsin, Area of Concern.

Escanaba River Non-Area of Concern Comparison Site

The Escanaba River (fig. 10, table 1) in Michigan's Upper Peninsula was selected as a non-AOC comparison site for the Lower Menominee River on the basis of similar climate and geology. In addition, both the Lower Menominee and the Escanaba Rivers are coldwater rivers with relatively high gradients and portions flowing over bedrock. Because of these similarities, the Lower Menominee and Escanaba Rivers would be expected to have similar benthos communities, despite the significantly smaller size of the Escanaba River drainage area (2,393 km^2) than that of the Lower Menominee River (10,490 km^2). Because of legacy contamination in the Escanaba River, there are fish consumption warnings for PCB and mercury (Michigan Department of Community Health, 2015) and some urban runoff. The sampling location (ESCA) was about 2 km downstream of Dam 1 near the boat launch at the mouth of the river.

Oconto River Non-Area of Concern Comparison Site

The Oconto River (fig. 11, table 1) was selected as a non-AOC comparison site for the Lower Menominee River. The Oconto has a smaller drainage area (2,502 km^2) than the other two rivers, but it is a coldwater stream with similar climate and geology. Despite historical contamination from paper mills and water-treatment facilities, conditions improved with the halting of paper pulping operations and improvements to water-treatment facilities (Rost and others, 1989). The sampling location (OCON) was about 1.8 km upstream of the mouth.

Ahnapee River Non-Area of Concern Comparison Site

The Ahnapee River (fig. 12, table 1) is a small river approximately 48 km northeast of the mouth of the Fox River. Although it drains to Lake Michigan rather than Green Bay and has a much smaller drainage area (274 km^2) than the Fox River (16,178 km^2), its proximity to the Fox River along with similar climate, latitude, and geology lends to a comparison. Other than water-treatment facilities, no industries directly discharge into the river. The sampling location (AHNA) was about 0.1 km downstream of the 2nd Street Bridge in Algoma, Wis.

Kewaunee River Non-Area of Concern Comparison Site

The Kewaunee River (fig. 13, table 1) is a small (354 km^2), predominantly agricultural watershed. Despite its smaller drainage area, it was chosen as a comparison site for the Fox and Sheboygan Rivers because of similar climate, latitude, geology, and land use. Sediment sampling in 1988 by the WDNR found moderate levels of petroleum products, total phosphorus, lead, and chemical oxygen demand in sediments (Wisconsin Department of Natural Resources and Lakeshore Basin Partnership Team, 2001a). Along with nonpoint source contaminants from agricultural and urban runoff in the watershed, water-treatment facilities and several industries in the watershed may contribute contaminants to the river. The sampling location (KEWA) was near the State Highway 42 Bridge.

Manitowoc River Non-Area of Concern Comparison Site

The Manitowoc River (fig. 14, table 1) is approximately 40 km north of the Sheboygan River. It was selected as a comparison site for the Sheboygan, Milwaukee, and Menomonee Rivers on the basis of similarities in drainage-area size, climate, latitude, geology, and land use. The land cover is predominantly agricultural and includes areas of protected wetlands and urban land cover primarily near the river mouth. Multiple water-treatment facilities and industries discharge to the river, which has had a fish consumption advisory from the mouth upstream to the first dam for more than 35 years because of PCBs (Wisconsin Department of Natural Resources, 2015b). In addition, continued monitoring takes place at an EPA Superfund site, which borders the left bank of the river about a mile upstream from its mouth, where studies and cleanups took place from 1988 through 1994 to address volatile organic compounds, PAHs, and cyanide (U.S. Environmental Protection Agency, 2015). Despite these known chemical issues, this river was selected as a non-AOC comparison site because it has a setting similar to the Sheboygan, Milwaukee, and Menomonee River AOCs and is not an AOC. The sampling location (MANI) was just upstream of the 10th Street Bridge.

Root River Non-Area of Concern Comparison Site

The Root River (fig. 15, table 1) was selected as a comparison site for the Milwaukee and Menomonee Rivers on the basis of its similar climate, latitude, geology, and land use as well as a drainage area comparable in size to that of the Menomonee River. The Root River drainage area is approximately 514 km^2, and the land use is mostly urban in the headwaters near Milwaukee, agricultural in the middle drainage area, and highly urban at the mouth in Racine. There are fish consumption advisories for PCBs and heavy metals for the Root River, and several water-treatment facilities and industries discharge into it (Wisconsin Department of Natural Resources and Lakeshore Basin Partnership Team, 2001b). The sampling location (ROOT) was near the corner of Villa Street and Water Street, upstream of the State Street Bridge.

Figure 10. U.S. Geological Survey sampling locations for benthos and plankton communities in the Escanaba River, Michigan.

Figure 11. U.S. Geological Survey sampling locations for benthos and plankton communities in the Oconto River, Wisconsin.

Figure 12. U.S. Geological Survey sampling locations for benthos and plankton communities in the Ahnapee River, Wisconsin.

Figure 13. U.S. Geological Survey sampling locations for benthos and plankton communities in the Kewaunee River, Wisconsin.

Figure 14. U.S. Geological Survey sampling locations for benthos and plankton communities in the Manitowoc River, Wisconsin.

Figure 15. U.S. Geological Survey sampling locations for benthos and plankton communities in the Root River, Wisconsin.

Data Collection

Benthos and plankton samples were collected from each of the 10 sites during 3 sampling events approximately 6 weeks apart in late May/early June, mid-July, and late August (hereafter, for simplicity, the 3 sampling events will be referred to as “seasons”). All sites were nonwadable, and therefore sampling was done by boat. All sampling at AOCs was done within AOC boundaries. During each sampling event, in situ water-quality measurements were taken for pH, specific conductance, dissolved oxygen, and water temperature by use of a YSI sonde (appendix 1). Samples taken at each site consisted of two benthos and two plankton sampling techniques. Benthic grabs, plankton samples, and water-quality measurements were taken at the same location; Hester-Dendy (HD) artificial substrate samplers were deployed within 0.4 km of the Ponar samples. Collection methods were similar to those used in 2012 and described in Scudder Eikenberry and others (2014).

Benthos Collection and Processing

Benthos samples were collected at each site by two methods: dredge samples and HD artificial substrate samplers (U.S. Environmental Protection Agency, 1994; Weigel and Dimick, 2011). Three to four dredge samples were collected and composited into one sample per location by using a standard Ponar® dredge that collected a 229- by 229-millimeter (mm) sample from the upper layer of bottom sediment (fig. 16; U.S. Environmental Protection Agency, 2010a). A small amount of sediment (<50 grams) from each composited dredge sample was split between two plastic bags for analyses of sand-silt-clay fractions and volatile-on-ignition of sediment (appendix 2). Large debris and empty shells in the remaining composite sample were examined for any attached invertebrates before being discarded, and fines were removed by sieving. The retained debris and organisms were stained with rose bengal dye and preserved with 10-percent buffered formalin (pH 7). Sediment samples were analyzed for sand-silt-clay fractions by the University of Wisconsin Soil and Plant Analysis Laboratory through the Wisconsin State Laboratory of Hygiene (WSLH), except for five samples analyzed by the USGS Kentucky Water Science Center Sediment Laboratory because of low mass. Volatile-on-ignition of sediment analyses were done at the USGS Wisconsin Water Science Center in Middleton, Wis. (Fishman and Friedman, 1989; Wentworth, 1922). Identification and enumeration of taxa in dredge samples was done by the Lake Superior Research Institute (LRSI) at the University of Wisconsin-Superior (U.S. Environmental Protection Agency, 2010b) (appendix 3).

The second type of benthos sample was collected by using HD samplers (Weigel and Dimick, 2011). At each location, two concrete blocks with two HD samplers each were deployed for 6 weeks during each season, and each block was independently anchored to an immobile structure such as a wing wall or pier piling within one-fourth of a mile of the dredge sampling location(s) (fig. 17). After about 6 weeks, to allow adequate time for colonization by invertebrates, the HD samplers and blocks were retrieved. Once retrieved, three of the four HD samplers were randomly chosen to represent the benthos community at the site, and the fourth HD sampler was used as a backup if one or more of the HD samplers was compromised. Samplers were then reassembled and redeployed for the next sampling event or were replaced if necessary. All organisms were scraped off and rinsed with tap water through a 500-micrometer (µm) wash frame, composited into one sample per season for each site, stained with rose bengal dye, and preserved with 10-percent buffered formalin. Identification and counting of taxa in HD samples was done by the LRSI (U.S. Environmental Protection Agency, 2010b) (appendix 4).

Figure 16. A Ponar dredge being retrieved with a sediment grab for a benthos community sample.

Figure 17. Hester-Dendy artificial substrate samplers retrieved for benthos community assessment.

Plankton Collection and Processing

Plankton samples for each site consisted of a net sample to capture larger zooplankton and a set of whole water samples to capture phytoplankton.

Zooplankton samples were collected by plankton net tows from a depth of 5 meters (m) to the surface with a 63-micrometer mesh net, as described in the EPA's standard operating procedures for zooplankton sample collection and preservation (U.S. Environmental Protection Agency, 2010f). If the available depth was less than 5 m, multiple tows were taken from just above the bottom to the surface until 5 m total depth was sampled. After each tow, the net was sprayed down with tap water to wash organisms into the sampling bucket, and samples were composited in a 500-milliliter (mL) plastic bottle. Samples were preserved on shore with glutaraldehyde to a one-percent final solution (fig. 18). Preserved samples were sent to the WDNR for zooplankton identification and enumeration (U.S. Environmental Protection Agency, 2010e) (appendix 5).

For the phytoplankton samples, a Kemmerer vertical water sampler was used to collect a set of five whole water samples at 1-m depth intervals from 1 m below the surface to just above the bottom (U.S. Environmental Protection Agency, 2010d). The samples from each depth were composited in a bucket for subsampling and processing on shore (fig. 19). Several subsamples were taken from this composite sample. Approximately 500 mL of the composite was placed in a plastic bottle, preserved with glutaraldehyde to a 1-percent final solution, and sent to the WSLH for identification and enumeration of soft algae phytoplankton (blue-greens, cryptomonads, desmids, dinoflagellates, euglenoids, and greens) (Karner, 2005) (appendix 6). Approximately 1 liter of the sample was placed in a plastic bottle, preserved with glutaraldehyde to

Figure 18. A plankton net being washed to collect a zooplankton community sample.

Figure 19. A Kemmerer vertical water sampler, after retrieval from depth, being emptied into a sample splitter to collect samples for phytoplankton community, chlorophyll *a*, and suspended solids.

a 1-percent final solution, and sent to the WDNR for diatom phytoplankton identification and enumeration (U.S. Environmental Protection Agency, 2010c) (appendix 7). A minimum of 50 mL was filtered in the field for chlorophyll *a* with a Millipore type SM membrane filter (47-mm diameter 5.0-µm pore size), which was then placed in an analysis vial, wrapped in aluminum foil, and preserved with dry ice until delivery to the WSLH for analysis (Kennedy-Parker, 2011) (appendix 8). A minimum of 50 mL was filtered for total suspended solids and volatile suspended solids through a Whatman glass fiber filter (1.5-µm pore size), which was then wrapped in aluminum foil, placed in a petri dish, and preserved with dry ice until delivery to the WSLH (American Public Health Association, American Water Works Association, and Water Environment Federation, 2006) (appendix 8).

Quality Assurance and Quality Control

Quality assurance and quality control (QA–QC) samples were collected during each sampling period to evaluate field variability of taxonomic results. Primary and replicate samples were collected at two sites, the Sheboygan River AOC and its non-AOC comparison site, the Manitowoc River. Primary and replicate samples were compared by using the SIMPER routine in PRIMER software to compare similarity matrixes of the taxonomic data (Clarke and Gorley, 2006). Similarities greater than 60 percent were considered acceptable for QA–QC purposes (Kelly, 2001). Primary and replicate samples at both sites had similarities greater than 60 percent except for fall (late August) diatom samples. Because of the fall diatom samples, similarities for fall combined algae samples were also low (table 2). Fall diatom densities in Sheboygan River primary and replicate samples were dominated (>75 percent) by one colony-forming centric taxon, and overall there were fewer taxa and greater densities in the replicate samples. Fall diatom densities in Manitowoc River primary and replicate samples were dominated by other colony-forming centric taxa. It is often difficult to precisely characterize biological communities that have patchy distributions and low abundances, especially algal blooms that result from eutrophication. By use of relative abundances for combined algae samples in comparisons among AOCs, the effect of the fall diatom taxa differences on the overall phytoplankton comparisons was lessened. Overall, however, QA–QC results indicated minimal variability among field replicates within each season for most taxonomic groups.

Table 2. Quality assurance and quality control (QA–QC) results for replicate samples of benthos and plankton collected in 2014 at the Sheboygan and Manitowoc Rivers, Wisconsin, showing similarity for relative abundance of taxa collected within each season.

[Similarities greater than 60 percent, indicating QA–QC results within acceptable limits, are in gray. Refer to table 1 for the complete site and subsite names]

Site	Taxonomic group	Spring similarity (percent)	Summer similarity (percent)	Fall similarity (percent)	Average similarity (percent)
Sheboygan River	Benthos (combined)	77.5	69.6	64.1	70.4
	Zooplankton with nauplii	85.6	78.2	83.6	82.5
	Diatoms	71.5	66.6	34.8	57.6
	Soft algae	82.5	84.4	84.9	83.9
	Algae (combined)	73.4	69.1	52.2	64.9
Manitowoc River	Benthos (combined)	74.2	67.5	66.4	69.4
	Zooplankton with nauplii	79.4	72.3	84.4	78.7
	Diatoms	60.2	62.3	34.1	52.2
	Soft algae	78.0	98.2	89.5	88.6
	Algae (combined)	63.3	66.3	46.2	58.6

Summary

This report describes study areas and field sampling methods and provides data collected in 2014 by the U.S. Geological Survey, in cooperation with the Wisconsin Department of Natural Resources and the U.S. Environmental Protection Agency, for characterization of benthos (benthic invertebrates) and plankton (zooplankton and phytoplankton) communities at 4 Area of Concern (AOC) and 6 non-AOC rivers and harbors along the western Lake Michigan shoreline. The 4 AOCs are the Lower Menominee River, Lower Green Bay and Fox River, Sheboygan River, and Milwaukee Estuary (Milwaukee River, Menomonee River, and Milwaukee Harbor); the 6 non-AOCs sampled for comparison with the AOCs are the Escanaba River, Oconto River, Ahnapee River, Kewaunee River, Manitowoc River, and Root River. In addition to the data on the abundance and distribution of benthos and plankton taxa at these sites, ancillary data are included for sediment characterization (percentages of sand, silt, and clay), algal biomass (chlorophyll *a*, total and volatile suspended solids), and water quality (water temperature, pH, specific conductance, and dissolved oxygen). The data collection described in this report, as well as data collection in the same study areas and by the same field sampling methods in 2012, are part of a study designed to assess the status of the benthos and plankton communities in the AOCs in comparison to those at the non-AOCs for evaluation of the related Beneficial Use Impairments at the AOCs.

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Appendixes 1–8

The data files listed below are included as part of U.S. Geological Survey (USGS) Data Series 1000 and are available for download at http://dx.doi.org/10.3133/ds1000. The data were collected in 2014 as part of the USGS benthic invertebrate and plankton community data for selected rivers and harbors along Wisconsin’s Lake Michigan shoreline. See the report text for details about the study and for information on collection and processing of all data. The data files are available as Microsoft Excel (.xlsx) and comma-separated value (.csv) files formatted to properly display the data. Federal Geographic Data Committee-compliant metadata accompany these tabular datasets.

Appendix 1. Water-Quality Measurements Made In Situ with a Ysi Sonde, Collected as Part of the U.S. Geological Survey Benthos and Plankton Community Data for Selected Rivers and Harbors Along Wisconsin's Lake Michigan Shoreline, 2014

[Excel and .csv files available at http://dx.doi.org/10.3133/ds1000]

Appendix 2. Sediment Size Fractions and Volatile-On-Ignition Data for Composite Benthic Grabs Made With a Ponar Dredge, Collected as Part of the U.S. Geological Survey Benthos and Plankton Community Data for Selected Rivers and Harbors Along Wisconsin's Lake Michigan Shoreline, 2014

[Excel and .csv files available at http://dx.doi.org/10.3133/ds1000]

Appendix 3. Invertebrate Taxonomic Data for Composited Benthic Grabs Made With a Ponar Dredge, Collected as Part of the U.S. Geological Survey Benthos and Plankton Community Data for Selected Rivers and Harbors Along Wisconsin's Lake Michigan Shoreline, 2014

[Excel and .csv files available at http://dx.doi.org/10.3133/ds1000]

Appendix 4. Invertebrate Taxonomic Data for Composited Hester-Dendy Artificial Substrate Samplers, Collected as Part of the U.S. Geological Survey Benthos and Plankton Community Data for Selected Rivers and Harbors Along Wisconsin's Lake Michigan Shoreline, 2014

[Excel and .csv files available at http://dx.doi.org/10.3133/ds1000]

Appendix 5. Zooplankton Taxonomic Data for Composited Plankton Tows, Collected as Part of the U.S. Geological Survey Benthos and Plankton Community Data for Selected Rivers and Harbors Along Wisconsin's Lake Michigan Shoreline, 2014

[Excel and .csv files available at http://dx.doi.org/10.3133/ds1000]

Appendix 6. Soft Algae Taxonomic Data for Composited Water Samples from a Kemmerer Vertical Water Sampler, Collected as Part of the U.S. Geological Survey Benthos and Plankton Community Data for Selected Rivers and Harbors Along Wisconsin's Lake Michigan Shoreline, 2014

[Excel and .csv files available at http://dx.doi.org/10.3133/ds1000]

Appendix 7. Diatom Taxonomic Data for Composited Water Samples from a Kemmerer Vertical Water Sampler, Collected as Part of the U.S. Geological Survey Benthos and Plankton Community Data for Selected Rivers and Harbors Along Wisconsin's Lake Michigan Shoreline, 2014

[Excel and .csv files available at http://dx.doi.org/10.3133/ds1000]

Appendix 8. Chlorophyll *a*, Total and Volatile Suspended Solids for Composited Water Samples from a Kemmerer Vertical Water Sampler, Collected as Part of the U.S. Geological Survey Benthos and Plankton Community Data for Selected Rivers and Harbors Along Wisconsin's Lake Michigan Shoreline, 2014

[Excel and .csv files available at http://dx.doi.org/10.3133/ds1000]

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