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Status of Fish Communities and Stream Quality in the Lake Michigan Basin: 2001-2016

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Abstract

The Lake Michigan Basin was surveyed in 2016 as a part of the Statewide IDNR/IEPA Monitoring Program designed to evaluate the condition of Illinois' stream resources. The Lake Michigan Basin is composed of man-made channels, and modified natural channels, most of which no longer drain to Lake Michigan due to flow modifications and river reversals. Located in Northeastern Illinois, the watershed is dominated by urban land use. This report summarizes fish assemblage sampling, including fish species composition, distribution, and determination of stream quality using the Index of Biotic Integrity (IBI). Factors influencing fish assemblages and population characteristics for selected sportfish populations are also discussed. Current conditions were compared to previous surveys conducted in 2001, 2006, and 2011. A total of 2,725 fish representing 36 fish species from 12 families were collected at 17 stations in 2016. The total number of fish and fish species was low compared to less urbanized northeastern Illinois watersheds of similar size. Banded Killifish was the only State listed fish species collected in 2016. Non-native fishes included Common Carp, Goldfish, Round Goby, and Oriental Weatherfish. No Asian Carp were collected or observed. Although all stations were generally dominated by tolerant, generalist fish species, there were differences in composition among the stations depending on stream size, habitat quality, and location within the basin. In the Chicago River Sub-Basin, different fish assemblages were found in the areas above and below West River Park Dam as indicated by Non-parametric Multi-dimensional Scaling (NMDS) analysis based on similarity of species presence absence. Although conditions were more effluent-dominated and habitat limited in the man-made, navigable channels downstream of the dam, especially in the lower North Branch, there have been many more fish species collected there, due to its connection to Lake Michigan and other source populations. Removal of the dam, as planned in 2018 should benefit the upper North Branch, which has some natural stream corridors and less effluent impacts. Intolerant and key functional groups such as benthic invertivores were lacking throughout the Chicago River Sub-basin, resulting in low stream quality (IBI) ratings, ranging from 11 to 20 out of possible 60 points. In the Calumet River Sub-basin fish assemblages were also largely composed of tolerant varieties but varied among sites due to differences in channel size and habitat. Station HA-04 located on the larger navigation channel of the Little Calumet River was dominated by sunfishes; different than other stations in the Sub-basin, and more similar to the large, deeper, constructed channels in the Chicago River Sub-basin based on NMDS plots. Station HB-01, which is on the non-navigable section of the Little Calumet River, was much degraded due to low flow and prevalence of silt. Common Carp and Gizzard Shad, both very tolerant fishes, made up 95% of the total collection. Several of the smaller stream sites in the Sub-basin, including Butterfield, Creek, Tinley Creek, and Thorn Creek, had more natural habitat features including riffles, runs, and pools, resulting in slightly higher IBIs (24-29) compared to other Sub-basin stations (IBI = 8 -19). The most abundant sportfishes throughout the Lake Michigan Basin were Bluegill, Largemouth bass and Pumkinseed. Although most individuals were young-of-the-year and juveniles, some areas held catchable-sized fish, particularly the larger stream sites in the North Branch and Little Calumet River. Results of 2016 fish sampling in the Lake Michigan Basin suggest relatively stable conditions over the period since 2001 with little change in stream quality ratings. Currently, all IBI ratings are below the IEPA threshold for full support of aquatic life (≥41). However, conditions have improved in recent decades based on increased recreational usage, prompting recent revision of IEPA use designations and water quality standards. Further expansion and completion of the Deep Tunnel Project to capture additional combined sewer overflows (CSOs) will have further benefits. An expanding list of fish species, currently up to 73, indicates some potential for the system.

Introduction

The Lake Michigan Basin in Northeastern Illinois includes the most densely populated and heavily industrialized areas of Illinois. The waterways consist of a unique combination of man-made and extensively modified stream channels. In fact, few of the streams actually drain to Lake Michigan due to massive realignments which occurred in the late 19th and early 20th centuries, re-directing their flow to the Illinois River (IDNR 2000). Although the waterways were once severely polluted, advancements in waste water treatment and stormwater management have resulted in improved conditions (Dennison et al. 1998). Renewed interest in active and passive recreation has recently resulted in revision of the standards and use designations by the Illinois Pollution Control Board (IPCB 2015). Although much of the system remains impaired by continuing water quality and habitat problems, an expanding list of fish species indicates potential for the system, which is still also constrained by combined sewer overflows (CSOs). Planned expansion of the Deep Tunnel Project will help address this problem (MWRD.org), although other management concerns remain.

Comprehensive knowledge of stream resource condition is critical to any management or restoration effort. Illinois Department of Natural Resources (IDNR) and the IEPA maintain an ongoing statewide stream monitoring program to address this need, providing data on fish and macroinvertebrate assemblages as well as habitat, and water quality evaluation. Information from these surveys is used in watershed planning, fisheries management, permit review, and public outreach and education. Surveys are conducted every five years on all major river basins of the State, establishing a long-term database of stream condition.

Since 2001, four surveys have been completed in the Lake Michigan Basin, providing an opportunity to examine stream conditions over a 15 year period. This report summarizes the fish community sampling portion of the most recent survey conducted in 2016. Results are compared to previous surveys in 2001, 2006, and 2011 (Pescitelli et al. 2013) including community composition, fish species distribution, and determination of stream quality using the Index of Biotic Integrity (Smogor 2004). We also discuss factors influencing fish assemblages and examine population characteristics and trends for selected sportfish populations.

Watershed Description

The Lake Michigan Basin sampled in this study includes the Chicago River, and Little Calumet River Sub-Basins (Figure 1). Although both of these river systems historically drained to Lake Michigan, due to modifications in the late 1800's and early 1900's they now drain into the Illinois River through the Sanitary and Ship Canal, and Cal-Sag Channel, combined with water diversions from Lake Michigan (Moore et al 1998). This river system, also referred to as the Chicago Area Waterways System (CAWS), is characterized by extensive urban land use and channel modification for wastewater/ storm water conveyance and navigation (IDNR 2000). CAWS consists of 78 miles of man-made channels (IEPA 2008), covering areas which were historically wetland and marsh, some with no well defined stream channels.

The Chicago River sub-watershed includes the Chicago River, North Branch, South Branch, West Fork, Skokie River, and North Shore Channel (Figure 2) draining an area of about 265 square miles (IDNR 2000) in Lake and Cook Counties. In addition to the locks/water control structures at Chicago Harbor and Wilmette on the North Shore Channel, there is a low head dam at West River Park near the confluence of the North Shore Channel and the North Branch (Figure 2). The West River Park dam is a permanent barrier to fish movement, dividing the upper and lower areas of the North Branch. Two lock structures at the mouth of the Chicago River and at Wilmette on the North Shore Channel appear to allow some fish movement. There are two additional dams on the upper North Branch, upstream of West River Park (Figure 2) Tam O'Shanter and Chick Evens. The Wilmette Dam on the Skokie River was removed in 2016. West River Park and Tam O'Shanter are scheduled for removal in 2018, and the Chick Evans Dam with be dismantled in 2019. An un-passable concrete ramp is located at the mouth of Tinley Creek.

The Calumet River Sub-basin in Cook and Will Counties (Figure 3) covers approximately 260 square miles. This system includes the Calumet River, Grand Calumet River and Little Calumet River. The O'Brien Lock is located on the Calumet River, approximately seven miles in-land from Lake Michigan. Thorn Creek and its tributaries, Butterfield, North, and Deer Creeks, flow into the Little Calumet River. All of these streams used to flow into Lake Michigan, but now flow southwest into the Cal Sag Channel. Tinley Creek, a direct tributary to the Cal-Sag Channel drains an area of 13.1 square miles. The Cal-Sag Channel flows into the Chicago Sanitary and Ship Canal (CSSC) near Argonne

Nation Laboratory (Figure 1). Direct tributaries to Lake Michigan sampled in 2016 included, Waukegan River, and Kellogg Creek in Lake County (Figure 4).

Methods

Fish were sampled at 17 locations in 2016 (Table 1), nine in the Chicago River sub-basin (Figure 2), six in the Calumet River sub-basin (Figure 3) and two direct tributaries to Lake Michigan (Figure 4). All stations, or subsets of the 2016 sites have been sampled previously (Pescitelli and Rung 2013). Fish collection methods for the 2016 were the same as those used in prior surveys and followed standard IDNR guidelines (IDNR 2009). Selection of sampling gear at each location was based on stream channel width and depth. At wider, non-wadable stations, fish were sampled using a boat equipped with a 3500-watt, DC generator. Wadable tributary sites were sampled using a 30-ft. electric seine powered by a single-phase, 2400-watt AC generator (Bayley et al.1989). Where needed, upstream and downstream block nets were used to prevent escape and/or entry of fish into the sampling area. Sampling gear and other collection information is provided in Table 2. At all stations, larger fish specimens were weighed, measured, and returned to the stream. Smaller individuals too numerous or difficult to identify in the field were preserved in 10% formalin and processed in the laboratory.

Stations were sampled in late June, mid Augusts and early September. Discharge levels during the 2016 survey were near or slightly above normal as indicated by gaging stations located throughout the basin (USGS 2016, Figure 5).

In addition to a summary of basin-wide fish collections, individual summaries are presented for the Chicago River, Calumet River Sub-basins and for Lake Michigan direct tributaries. The Chicago River sub-basin was further divided into two areas, upstream and downstream of West River Park Dam (Figure 2). In addition to the lack of fish passage between these areas, they are also quite different in terms of depth, width, and degree of modification.

Non-parametric Multidimensional Scaling (NMDS) based on Bray-Curtis (1957) similarity analysis for fish species presence-absence was used to examine similarity of fish assemblages among sampling stations. The Index of Biotic Integrity (IBI, Smogor 2004) was calculated at each location. The IBI is a widely-used stream quality measurement based on attributes of the fish assemblage including: number and types of fish species

present; food, habitat, and spawning preferences; and tolerance to degradation. These attributes are evaluated using ten parameters or metrics based on comparison to established reference conditions for least impacted streams of the same size and same region of the state. IBI scores range from 0-60 with higher scores indicating better quality. The IBI developed by Smogor (2004) was intended for use primarily on wadable streams up to 100 feet in width, but includes a method which extrapolates for wider stream widths. A difference of >10 IBI points indicates "biological meaningful change" (Smogor 2004).

Results from the 2016 survey were compared to previous surveys for common stations. Scientific names for all fish species collected can be found in Table 3 and are not repeated in the text or other tables.

Results and Discussion

A total of 2,725 fish, representing 36 fish species from 12 families, were collected at 17 stations sampled in 2016 (Table 3). The State Threatened species, Banded Killifish was collected from one site in each of the sub-basins. This fish species first appeared in 2011 and since then has become wide-spread throughout the CAWS and upper Illinois River system. Four non-native fish species were present, including Common Carp, Goldfish, Round Goby and Oriental Weatherfish, all of which have been collected in previous surveys. No Asian Carps were collected or observed. We were unable to sample Plum Creek in 2016 due to elevated water levels, therefore the total number of species for the entire basin was lower compared to 2011 (Table 4).

Chicago River Sub-basin

Results for the Chicago River Sub-basin are presented for the area upstream and downstream of the West River Park Dam due to differences in stream size, habitat and water quality conditions (Figure 2). Downstream of the dam, the man-made channels of the lower North Branch, North Shore Channel, and South Branch, are deeper, more influenced by Combined Sewer Overflows (CSOs) and the North Side treatment plant effluent. Upstream of the dam the stream channels are smaller, shallower and more natural and less effluent dominated. Segments of the upper North Branch have been channelized while other areas retain their natural meandering character (Figure 2). The West River Park Dam, currently a barrier to fish migration, is scheduled for removal in 2018.

Fish composition and distribution. In the downstream area of the sub-basin below West River Park Dam, we collected 1,153 individuals at five locations (Table 5). A total of 21 fish species were recorded for all stations, ranging from eight at HCCA-04 and HC-02, to 15 at Oakton Avenue on the North Shore Channel. Tolerant fish species, Gizzard Shad, Common Carp and Golden Shiner were highest in abundance (Table 5). Three locations in the constructed channels of the North and South Branches (HC-01, HCC-02, and HCC-04) had habitat limitations due to the presence of steep, armored banks and little or no instream cover or flow diversity, which combined with water quality limitations had very low species richness range from 8 to 13 (Table 5). The North Shore Channel has shallower depths, vegetation, scattered woody debris, and overhanging tree cover, with more diverse habitat and cover than other man-made channels. For the two North Shore Channel stations, HCCA-02 at Oakton Street, upstream of the North Shore Treatment Plant, had higher fish species richness (Table 5), and different species composition than HCCA-04 located downstream of the North Shore Plant effluent, as observed in several previous surveys (Pescitelli and Rung 2013). The NMDS plot for 2016 stations indicated that HCCA-04 was different than all other basin stations (Figure 6), possibly due to direct water quality impacts from the treatment plant effluent. The lower Sub-basin is also impacted by 46 CSOs, 16 on the North Shore Channel and 30 on the lower North Branch (https://www.mwrd.org)

Stations upstream of the West River Park Dam had different fish species compositions compared to downstream, with higher abundance of Blackstripe Topminnow, Bluegill, Green Sunfish and White Sucker with a total 17 species (Table 6). The NMDS plot grouped the upstream stations together, and separate from the downstream stations, which were largely similar, except for HCCA-04 as noted above (Figure 6). Although not as highly modified as the deeper channels of the North Branch, much of the upstream-most segments on the West and Middle Fork have been straightened for drainage and flood conveyance (IDNR 2000). The Skokie River includes a dam which creates flood retention/recreational lagoons. (A small dam downstream of the Skokie Lagoon at Winnetka Road was removed in 2017). Habitat limitations, combined with extensive urban land cover, and isolation from recruitment sources resulted in low fish species richness ranging from 7 to 12 (Table). Much of the stream channel within Cook County downstream of the Skokie River is bordered by forest preserve and retains a more natural

stream corridor (IDNR 2000). Water quality limitations are also not as severe in the upper North Branch compared the lower North Branch (IEPA 2008), suggesting the upper North Branch could support more diverse fish assemblages.

All areas of the upper North Branch will potentially benefit from removal of the West River Park Dam in 2018. Despite habitat and water quality limitations there were a large number of species found downstream of the West River Park Dam, which do not occur upstream, presumably due to the connection to Lake Michigan. Native fish species found only downstream of the West River Park Dam in 2016 included: Pumpkinseed, Rock Bass, Spotfin Shiner, Emerald Shiner and Banded Killifish (Table 5). Northern Pike and Channel Catfish, both recently stocked in the North Shore Channel by IDNR, were also found only downstream of the dam in 2016; however, both species were collected in basin surveys prior to stocking. Intensive fish sampling has been ongoing on the North Shore Channel and lower North Branch since 2011 as a part of the monitoring program for Asian Carp. Although no Asian Carp have been found, from 2011 to 2015, there were a total of 37 native fish species from the North Shore Channel and lower North Branch which do not occur upstream of the West River Park Dam (Table 7). These include common stream species like Creek Chub, Sand Shiners, and Spotfin Shiner, as well as popular sport species (Smallmouth Bass and Rock Bass) and large-bodied suckers like Quillback, all of which could occupy the upper North Branch.

The absence of these fish species in the upper North Branch is due in part to previous water quality problems and possibly historic droughts, which could cause local species extirpations, especially for intolerant fish species. Larger migratory fishes like Channel Catfish, Smallmouth Bass and Quillback also migrate downstream to overwinter in larger water bodies. The West River Park dam prevents migration back into the upper Branch. Removal of the West River Park Dam in 2018 will open a potential recruitment source for the upper North Branch. Although some of the fish species occur at relatively low abundance, others are quite common below the West River Park Dam (Table 7). Further improvement in North Shore Channel water quality expected due to 2015 revision is water quality standards (see Summary Section below), would help increase fish abundance and diversity. IDNR and Friends of the Chicago River have received grants from the Chi Cal Fund to further improve habitat in the North Shore Channel, installing 200 concrete tube fish habitats and 4,500 emergent aquatic plants, Lizards Tails and Water

Willow. In addition, two other dams on the upper North Branch are in the planning stages and will be removed by 2019.

Index of Biotic Integrity (IBI)/ Stream Quality. Low overall fish species richness and lack of intolerant and specialist species in the North Branch and North Shore Channel, resulted in low Index of Biotic Integrity Scores for the 2016 Chicago River sub-basin, ranging from 11 to 20 out of a possible maximum of 60 (Table 8). Low scores were observed across all 10 metrics. As discussed above, low stream quality ratings result from water quality and habitat limitations, and fragmentation. IBI scores were somewhat lower in 2016, compared to 2011 especially at HCCC-06, where the IBI decreased more than 10 points (Table 13), indicating biologically meaningful change (Smogor 2004). A number of dead fish were observed at this station during sampling, suggesting a recent fish kill for which no apparent cause was observed. Scores at HCCB-13 on the West Fork have improved since 2011, with an upward trend since 2006, possibly due to installation of instream riffles in the City of Northbrook. No definitive trends were observed for other stations over the period 2001 to 2016 (Table 13).

Sportfishery. Bluegill was the most abundant sportfish fish species in the Chicago River sub-basin overall, with 159 collected. Although they were abundant and present at all stations, there were very few fish larger than four inches, with the majority of individuals between two and four inches in length (Figure 7). A total of 74 Largemouth Bass were collected for all nine Chicago River sub-basin stations. No individuals larger than 8 inches were found (Figure 7). Largemouth Bass and l catch rates for 2016 were similar to 2011 (Table 14). Other sportfish present in 2016 included Pumpkinseed Sunfish (n=12), Channel Catfish (n=2), and Northern Pike (n=1).

Calumet River Sub-basin

Fish composition and distribution. A total of 1,269 fish from 29 species were collected at six locations in 2016 Calumet River sub-basin survey (Table 9). Species richness at individual stations ranged from nine to 14. Plum Creek, which held 18 species in 2011, including several not found elsewhere in the basin, was not sampled in 2016 due to elevated water, reducing the overall species richness in 2016. The most abundant fish species collected in 2016 were Creek Chub, Bluntnose Minnow, and Central Stoneroller (Table 9). Composition of fish species varied among the stations due to differences in

habitat, stream size, and condition. The Little Calumet River at station HB-01 was among the most degraded, with substrate consisting primarily of fine silt with shallow, uniform water depth and lack of flow, unlike all other basin stations. Common Carp and Gizzard Shad, both very tolerant species, accounted for 94% of the total abundance. Station HA-04, on the larger navigation channel contiguous with the Cal Sag Channel, held 14 fish species (Table 9). Sunfishes were the most abundant species with fewer tolerant species compared to HB-01. Fish species richness and abundance at HA-04 were lower in 2016 compared to previous surveys (Pescitelli and Rung 2013) although no changes in habitat conditions were observed. Five State Threatened Five Banded killifish were collected at HA-04; however, this species has become very widespread through the CAWS. In the NMDS plot, HB-01 was more similar to the North Branch and North Shore Channel, other man-made channel, whereas HB-01 species composition was not similar to any other basin stations (Figure 6).

The other four stations in the Calumet River sub-basin (Thorn Creek, North Creek, Butterfield Creek, and Tinley Creek) were smaller stream sites with a different fish species composition compared to HB-04 and HB-01. Thorn, Butterfield, and Tinley Creeks held several small stream fish species such as Johnny Darter, Creek Chub, Central Stoneroller and several other native minnow fish species not found, or very rare, in other survey sites (Table 9). The similarity in these stream fish compositions at these smaller stream locations, and difference from other sites was indicated by their close grouping on the NMDS plot (Figure 6). North Creek (HBDA-01), although similar in size, was quite different than the other smaller streams in the Calumet sub-basin, as indicated on the NMDS plot (Figure 6), having very low gradient and low flow conditions, lacking the native minnows and sunfishes found at the other sites.

Index of Biotic Integrity/ Stream Quality. Stream quality ratings were generally low for the Calumet River sub-basin (Table 10). Station HB-01 on the Little Calumet River had the lowest rating with an IBI score of eight, while Butterfield Creek had the highest rating with an IBI of 29 out of a possible 60 points (Table 10). Butterfield Creek and Tinley Creek typically support higher IBI than other basin stations due to the presence of more natural stream habitat features (Pescitelli and Rung 2013). Overall, IBI scores in 2016 were similar to the previous survey in 2011, with no differences greater than seven among the sampling stations. Although Thorn Creek is highly incised, habitat features are present

with riffles and hard substrate. IBI scores on Thorn Creek have improved in each sample over the basin survey period since 2001, from 11 to 24 (Table 10). No trends were observed for other stations.

Sportfishery. A total of 23 largemouth bass were collected in the Calumet River sub-basin, for a catch rate of 7 per hour (Table 14); however, only one was over 10 inches in length (Figure 8). Thirty Bluegill were collected, only five of which exceeded five inches in length (Figure 8). Pumkinseed were also common (n=30), with three fish five inches or larger (Figure 8). Catch rates for Bluegill and Largemouth Bass were lower in 2016 compared to 2011, but within the range observed prior surveys (Table 14).

Lake Michigan Direct Tributaries

Species richness was low at both Waukegan River and Kellogg Creek, with a total of only eleven for both sites (Table 12). Kellogg Creek held nine fish species, including three State Threatened Banded Killifish. This species has become very abundant along much of the Lake Michigan shoreline (Phil Willink, pers. comm.), which is in close proximity to the Kellogg Creek sampling station (Figure 4). Only six species were collected in Waukegon River with a very low overall abundance of 35 fish (Table 12). Species compositions in the direct tributaries were not similar to other basin sites, or with each other, as indicated in the NMDS plots (Figure 6). IBI scores were low (Table 13), reflecting the degraded condition in these largely urbanized, isolated tributaries.

Summary

Results of the 2016 Lake Michigan Basin survey were similar to previous basin surveys, with low number of fish species and assemblages largely composed of tolerant, generalists. Species richness at individual stations ranged from 6 to 12, whereas, in more natural, less urbanized streams of similar size, species richness would be in the range of 16 to 32 (Smogor 2004). In addition to low fish species richness, productivity was also very low as indicated by overall catch rate in the Lake Michigan Basin, which was typically 50 to 75% percent lower than that found in more natural watersheds (Pescitelli and Rung 2009). The absence of intolerant fish species and key functional groups such as benthic invertivore fishes resulted in low IBI's across the Basin and suggests a lack of diversity in invertebrate food sources. Poor habitat, highly variable water quality conditions, and

altered flow regimes are prevalent throughout the urbanized waterways. All stations within the Lake Michigan Basin were low quality, with IBI's ranging from 8 to 29 (mean = 16.9), well below the threshold level (IBI>=41) for full support of aquatic life use (IEPA 2016). Sportfish numbers were down somewhat in 2016; however, catch rates for Largemouth Bass were higher in intensive Asian Carp monitoring, which over a 5 year period from 2011 to 2015 averaged 32 per hour in the North Shore Channel and 16 per hour in the Little Calumet River (Widloe and Pescitelli 2016). Younger, smaller fish are relatively abundant in many areas, indicating successful reproduction and/or recruitment.

Although current limitations remain, conditions have improved markedly in the Lake Michigan Basin since 1974 (Dennison et al. 1998) and have continued to improve, especially in recent years, as evidenced by the expanded use of the waterways for passive and active recreation. This increased interest and recognition of the waterways as important assets, prompted a revision of water quality standards (e.g. dissolved oxygen, temperature, fecal coliform and chlorides), adopted in 2015 (IPCB 2015). Effluent disinfection has also begun at the North Side and Calumet treatment plants and the North Shore Channel, North Branch and most of the Calumet/Cal Sag waterways have been upgraded from Non-contact to Recreation Use. Recent additions to the Deep Tunnel system have also helped reduce flooding and CSO inputs (MWRD.org). Further expansion and completion in 2029 will have additional benefits.

Another positive indicator is the expanding list of fish species found within the CAWS in recent years. A major benefit of the Asian Carp Monitoring Program has been expanded insight into fish distribution and abundance in the CAWS (Widlloe and Pescitelli 2016). Between 2011 and 2015, Asian Carp monitoring yielded 72 species of fish from the CAWS, including several intolerant species like Smallmouth Bass as well as riverine sucker species and native minnows. Although the presence of these fishes are encouraging, and indicate the ability of the systems to support additional diversity, many of these occurrences are inconsistent, and individual collections still yield a low number of fish species. This may be due to continuing problems with the 220 CSOs along the CAWS, which reported 43 output events in 2016 (MWRD.org). While water quality conditions maybe adequate or favorable much of the time, sporadic periods of poor conditions following CSOs are among the significant factors constraining further recovery of fish assemblages in the CAWS.

Another constraint within the CAWS is fragmentation and lack of a direct connection to a diverse riverine recruitment source. Lake Michigan provides a large reservoir of fish species, but does not support a high diversity of riverine species. The lower Des Plaines and Illinois Rivers have improved dramatically over the past decades (Gibson-Reinemer et al. 2017) and provide a very species-rich source. Unfortunately, the Brandon Road and Lockport lock and dams make this a less than direct connection to the CAWS. Still, there have been a number of species which have apparently traversed the locks and become established, or present in both the CAWS and in the upper Des Plaines River (Pescitelli and Rung 2013). More recently evidence has been found using microchemistry that fish can move through the Brandon Lock (Snyder et. al. 2018). Plans to establish a barrier for Asian Carp at the Brandon Lock (ref) will also block native fishes and may inhibit re-colonization of fish and mussel species from the Illinois River System into the upper Des Plaines River and CAWS and could impede their recovery.

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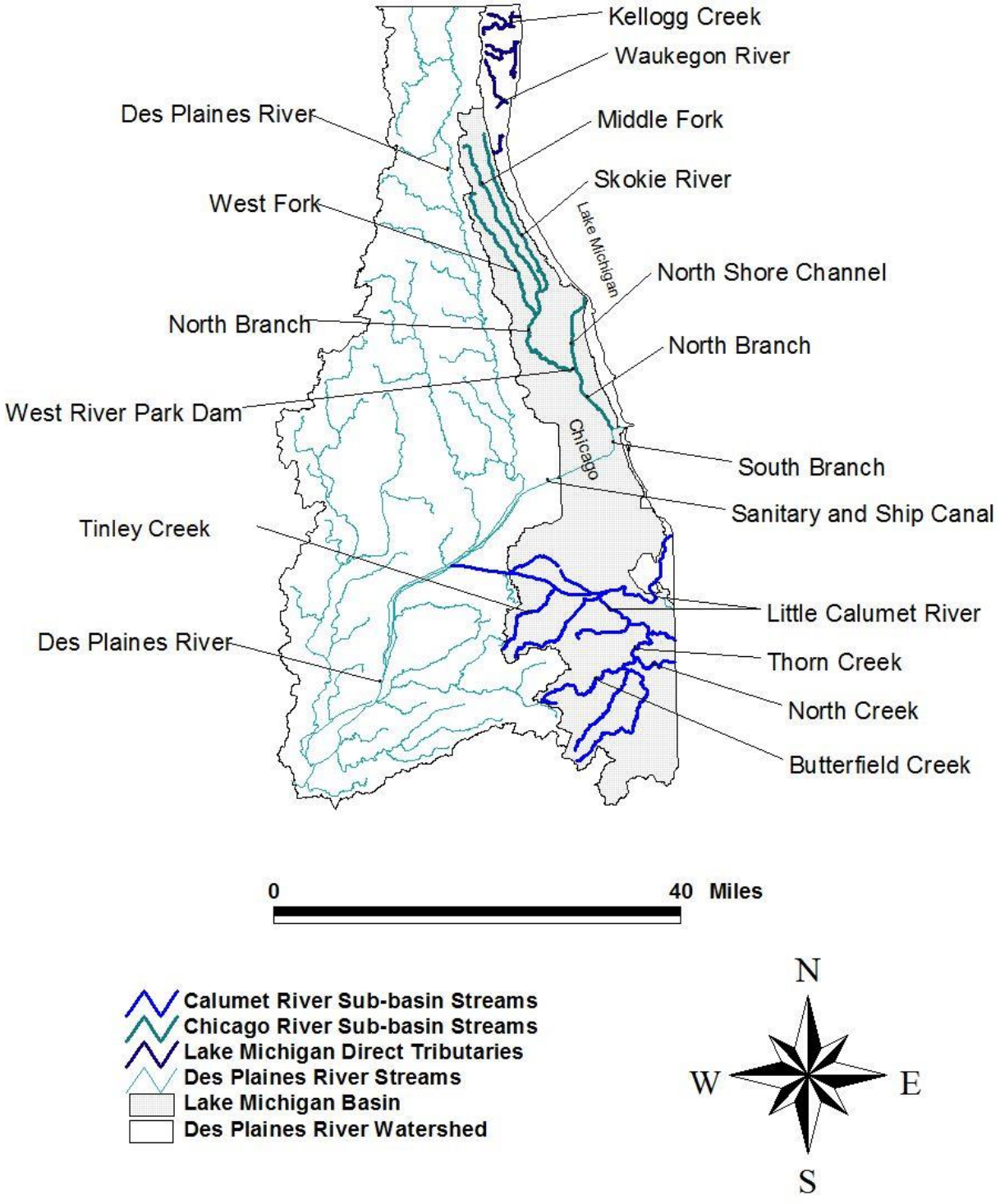


Figure 1. Lake Michigan Basin with Chicago River, Calumet River and Direct Tributary streams.

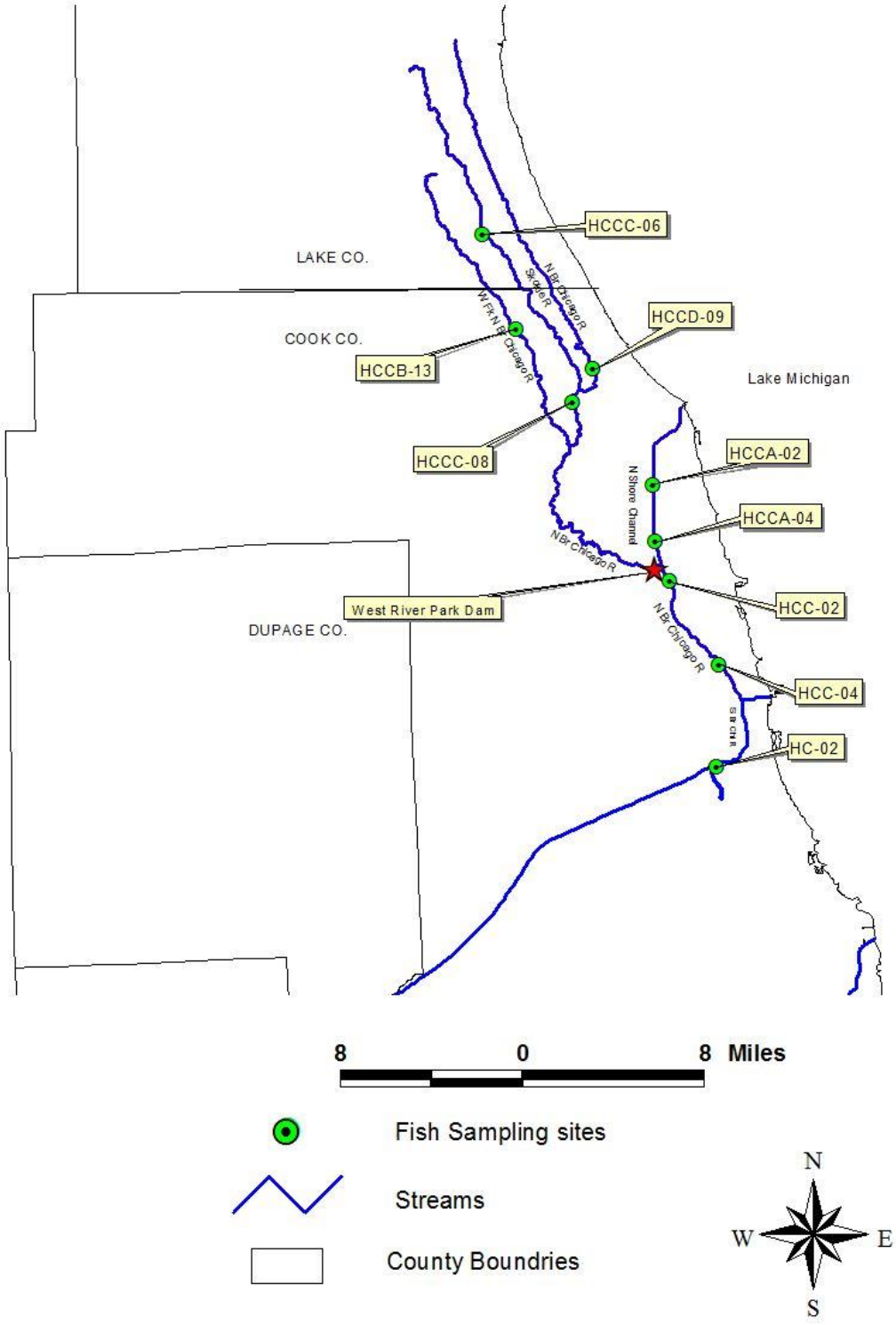


Figure 2. Fish sampling stations for the 2016 Lake Michigan Basin survey, Chicago River sub-basin including location of the West River Park Dam.

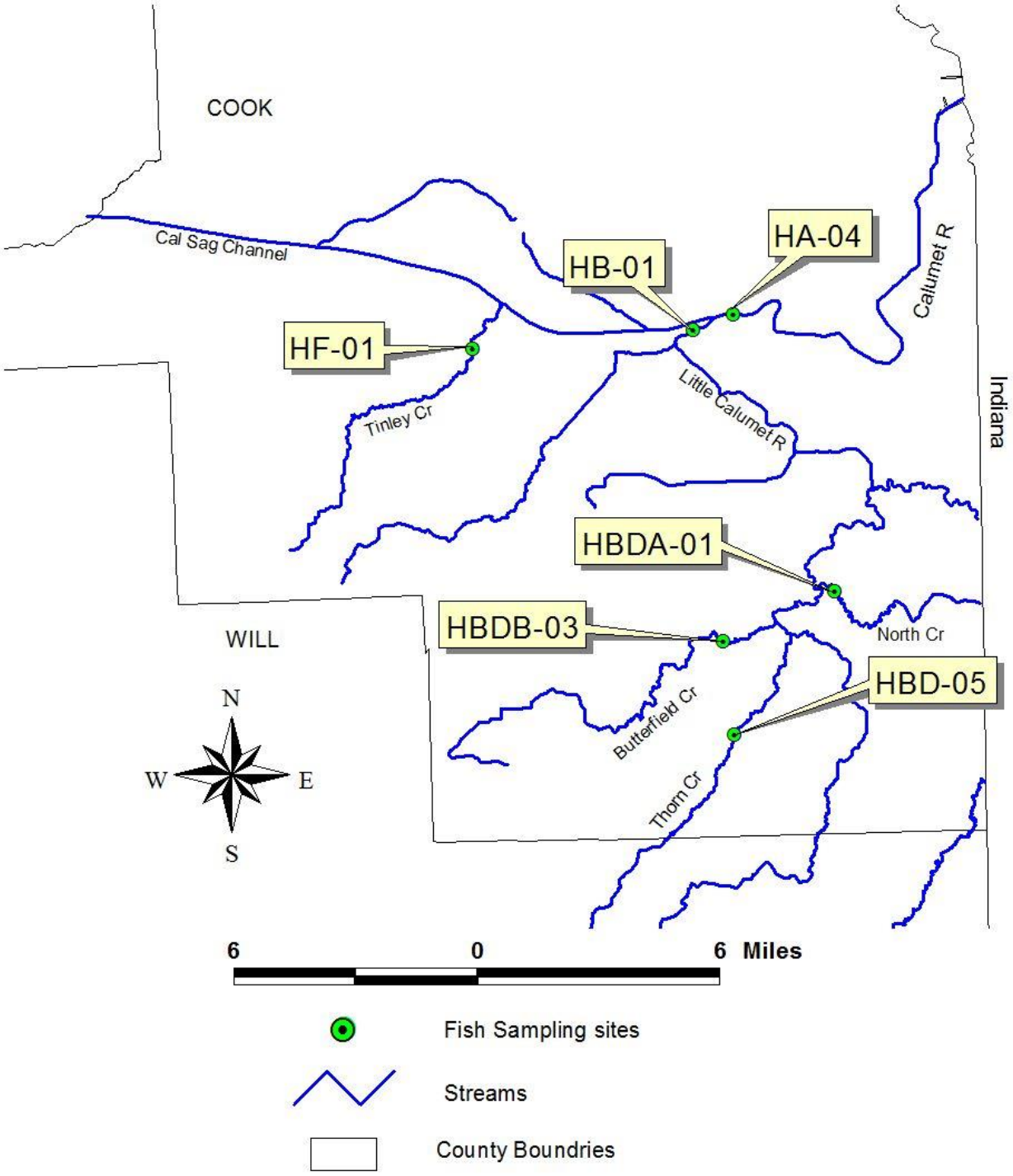


Figure 3. Fish sampling stations for the 2016 Lake Michigan Basin Survey, Little Calumet River sub-basin.

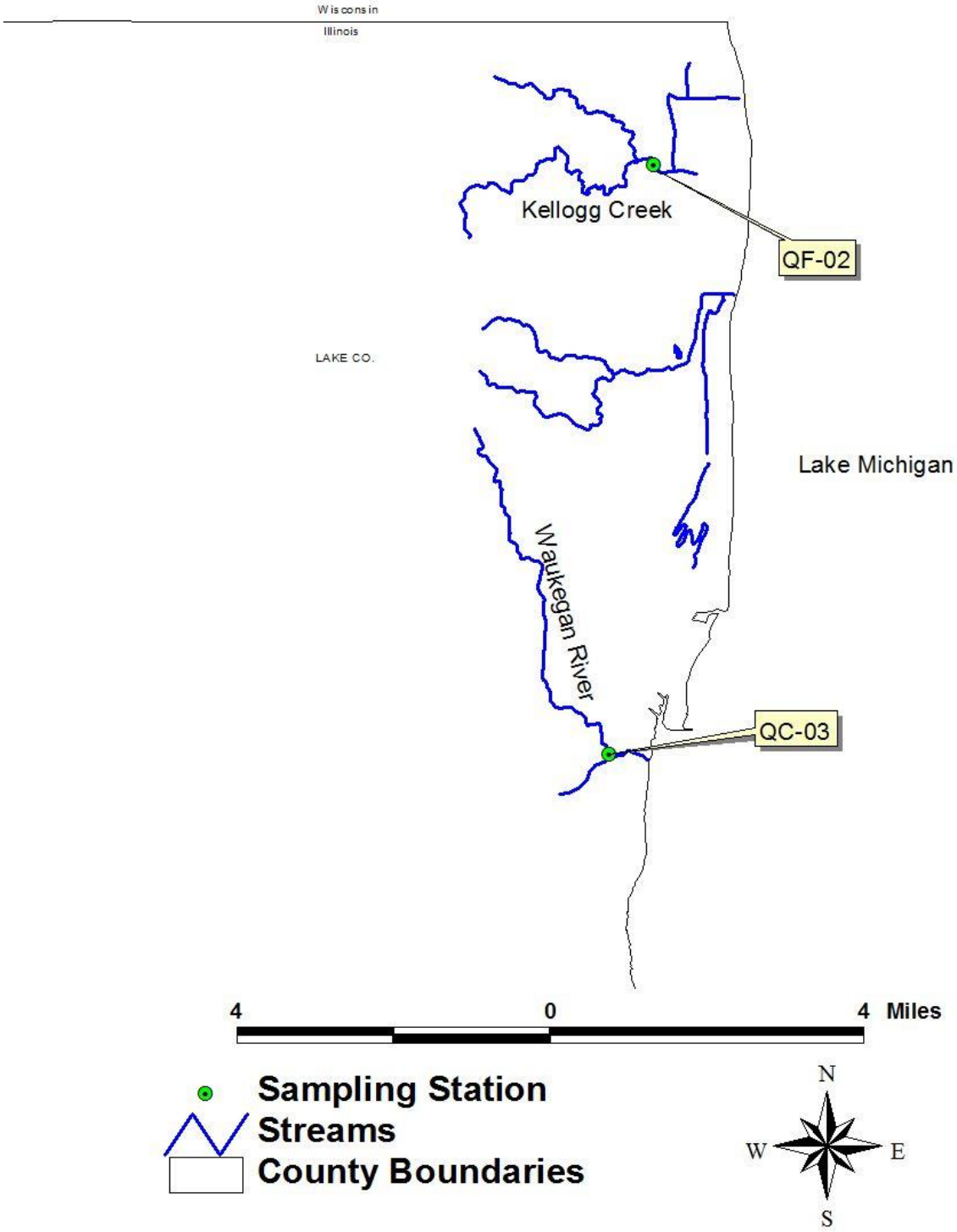
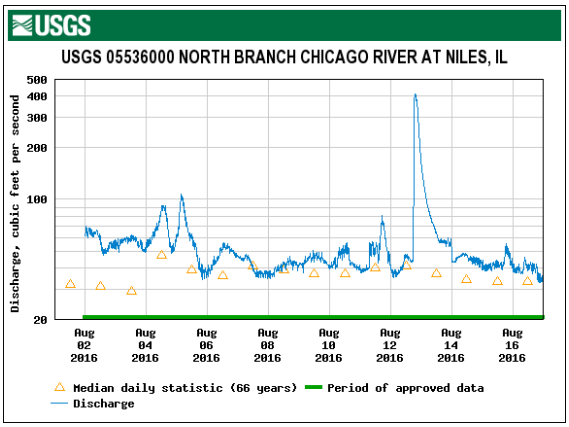
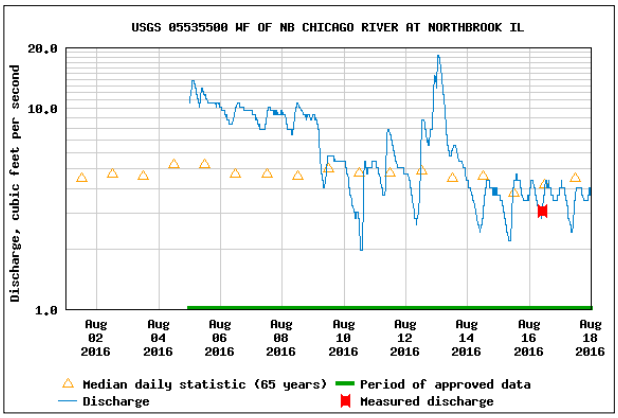
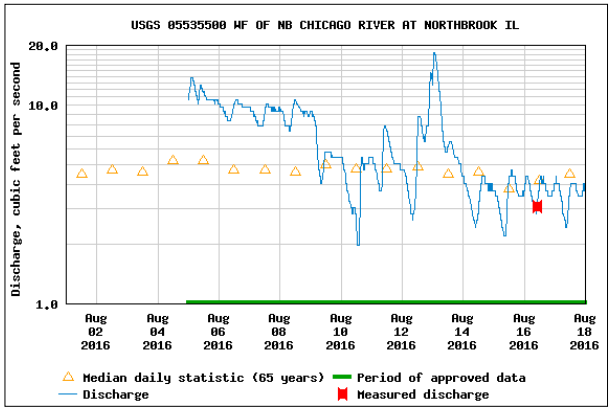


Figure 4. Sampling Station for the 2016 Lake Michigan Basin Survey; direct tributaries to Lake Michigan.







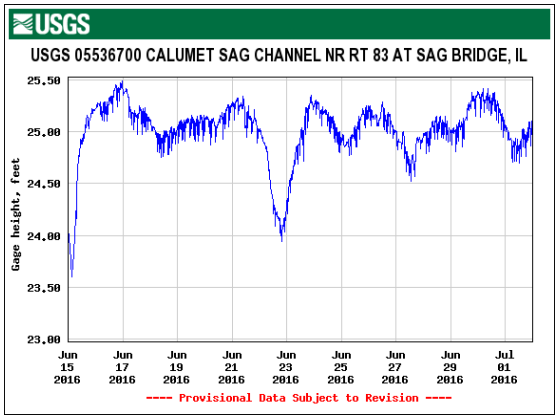


Figure 5. USGS daily discharge for selected sites during the 2016 Lake Michigan Basin survey.

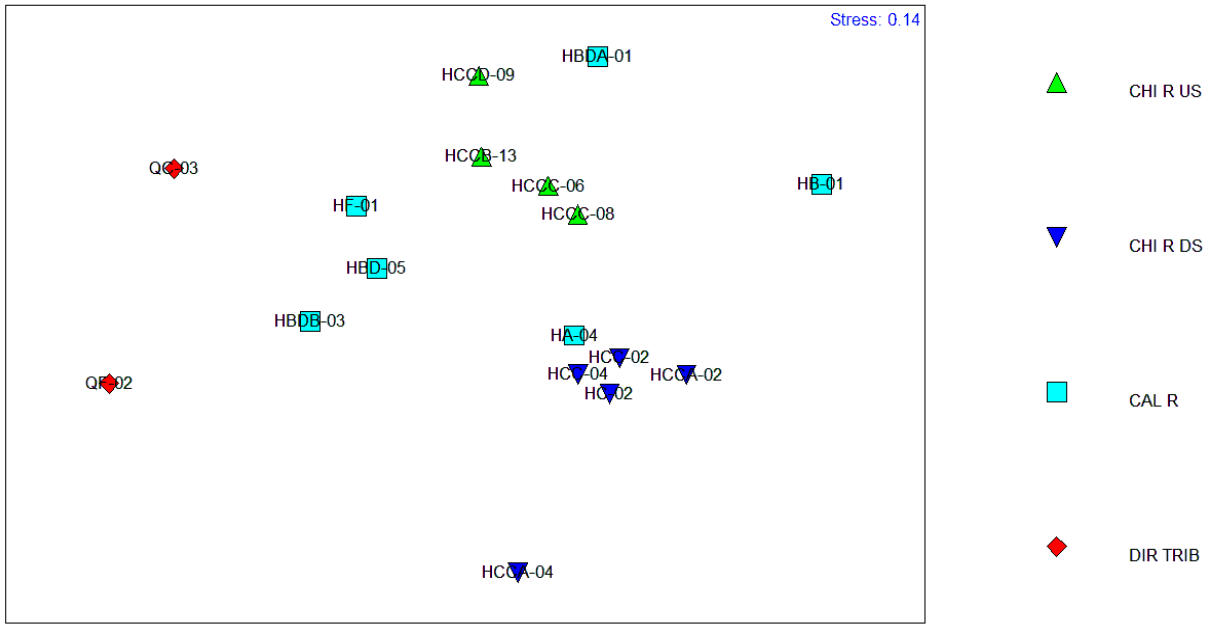


Figure 6. Non-parametric multi-dimensional scaling (NMDS) plot, based on Bray-Curtis (1957) similarity index for fish species presence-absence for 2016 Lake Michigan Basin fish sampling locations.

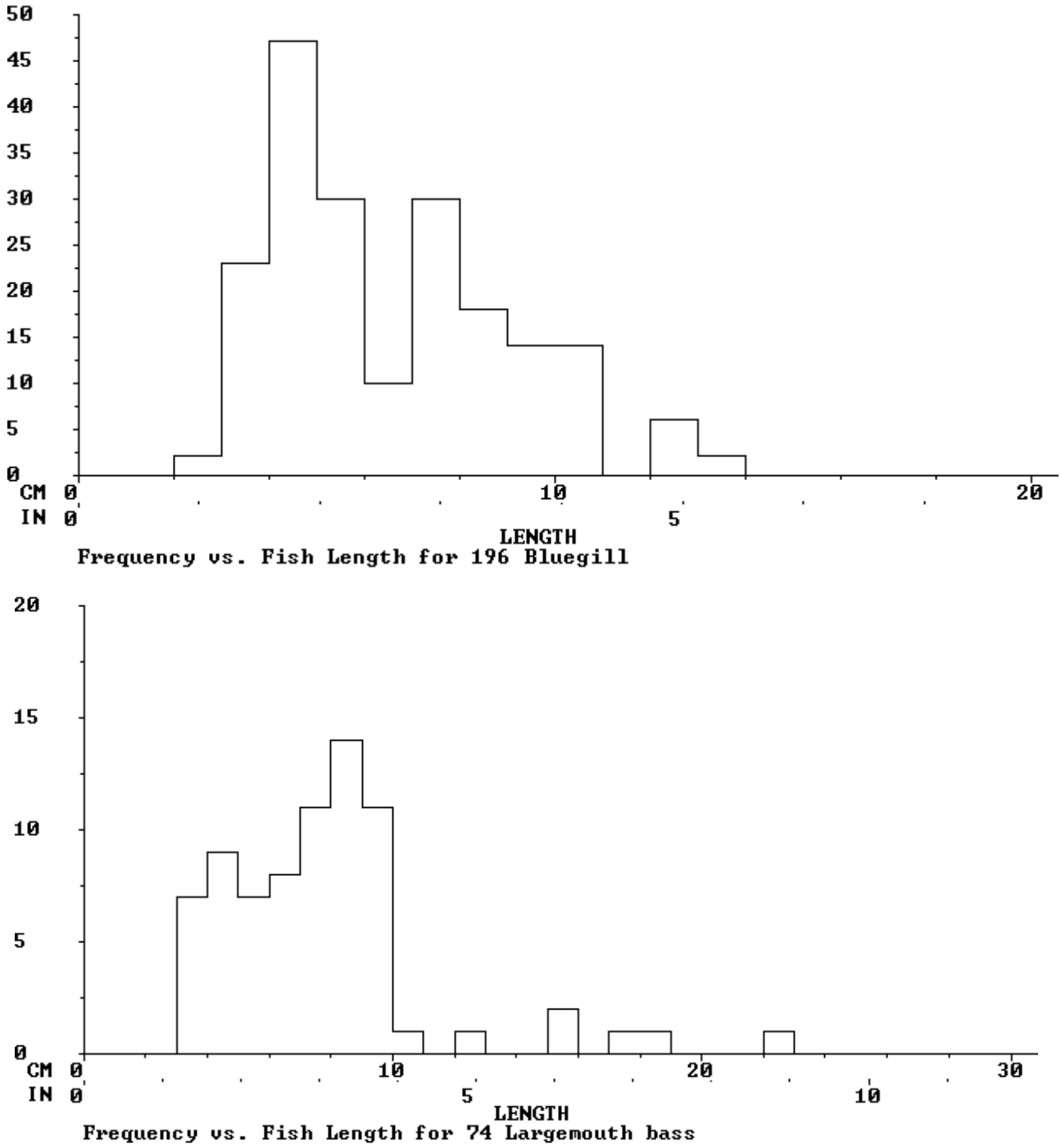
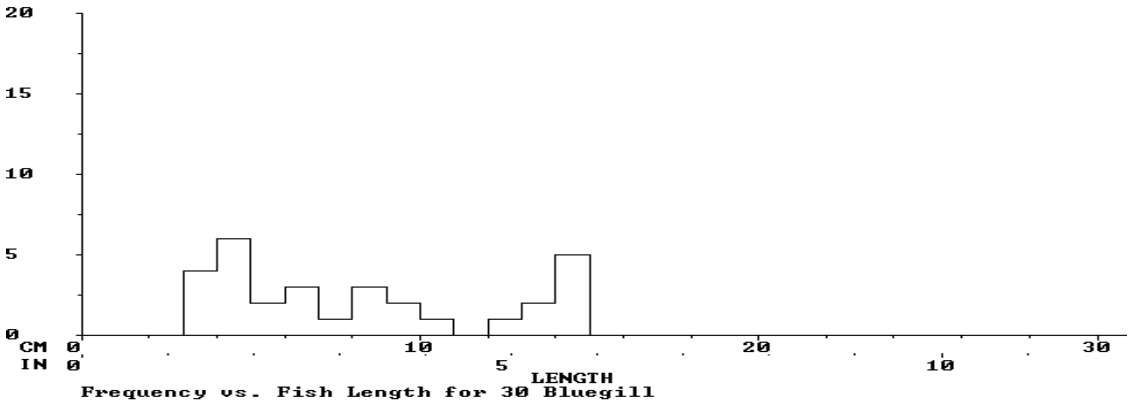
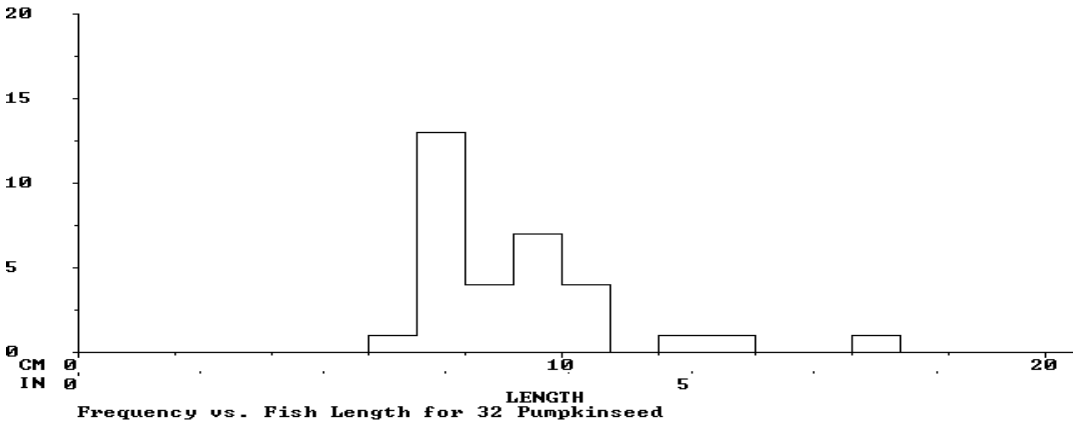


Figure 7. Length-frequency distribution of Bluegill (top) and Largemouth Bass (bottom) from the 2016 Chicago River sub-basin.





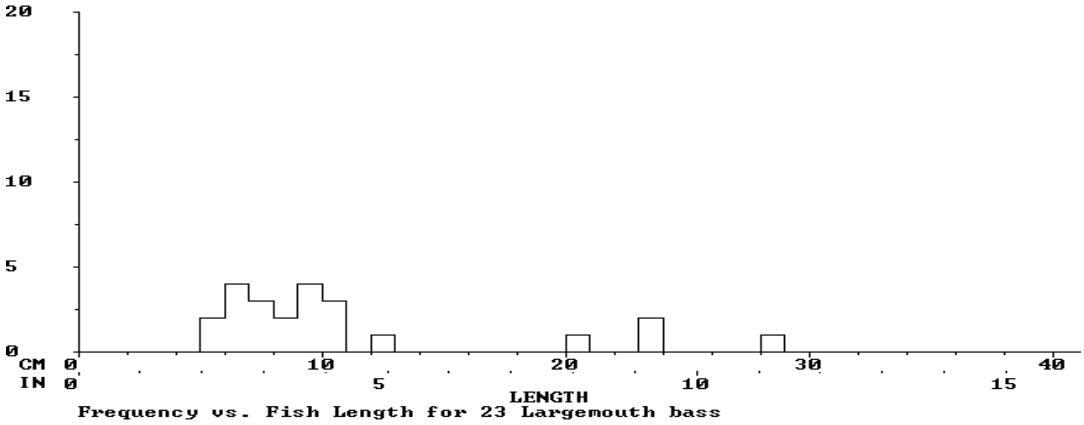


Figure 8. Length-frequency distribution of Bluegill (top), Largemouth Bass (middle) and Pumpkinseed (bottom) for the 2016 Calumet River sub-basin.

Table 1. Location of fish sampling stations for the 2016 Lake Michigan Basin Survey, including sub-basin designation, IEPA station code, stream name, and other location details. Chicago River - Upstream is located upstream of the West River Park Dam; Chicago River Downstream is located downstream of the West River Park Dam. The West River Park Dam is at the confluence of the North shore Channel and the Upper North Branch (41.973959, -87.704714).

Sub-basin	IEPA CODE	STREAM NAME	LOCALITY	COUNTY	LATITUDE	LONGITUDE
Chicago River - Upstream	HCCB-13	WEST FORK N BR CHICAGO RIIVER	WALTERS AVE BR IN NBROOK	COOK	42.127500	-87.824278
	HCCC-06	MIDDLE FORK N BR CHICAGO RIVER	1.1 MI NE DEERFIELD at DEERFIELD HIGH SCHOOL	LAKE	42.187900	-87.851200
	HCCC-08	MIDDLE FORK N BR CHICAGO RIVER	EAST LAKE AVE. 1 MI WSW OF I 90, GLENVIEW	COOK	42.079750	-87.777300
	HCCD-09	SKOKIE RIVER	WILLOW RD BR NR NORTHFIELD	COOK	42.101350	-87.758990
Chicago River - Downstream	HCCA-02	NORTH SHORE CHANNEL	OAKTON ST SKOKIE	COOK	42.026340	-87.709940
	HCCA-04	NORTH SHORE CHANNEL	PETERSON AV CHICAGO	COOK	41.990250	-87.709030
	HCC-02	NORTH BRANCH CHICAGO RIVER	WILSON AV CHICAGO	COOK	41.964640	-87.697090
	HCC-04	NORTH BRANCH CHICAGO RIVER	NORTH AV CHICAGO	COOK	41.910680	-87.656840
	HC-02	SOUTH BRANCH CHICAGO RIVER	LOOMIS ST. 0.9 MI WSW OF I 90-94 CHICAGO	COOK	41.845698	-87.660837
Clumet River	HA-04	LITTLE CALUMET	HALSTED ST CHICAGO	COOK	41.657380	-87.641290
	HB-01	LITTLE CALUMET	S ASHLAND AV RIVERDALE	COOK	41.651760	-87.660520
	HBD-05	THORN CREEK	RT 30 BR CHICAGO HEIGHTS	COOK	41.506010	-87.644700
	HBDA-01	NORTH CREEK	COTTAGE GROVE NE GLENWOOD	COOK	41.556860	-87.595770
	HBDB-03	BUTTERFIELD CREEK	CHICAGO RD HOMEWOOD	COOK	41.539860	-87.649540
	HF-01	TINLEY CREEK	135TH ST BR NR CRESTWOOD	COOK	41.646640	-87.766460
Direct Tributary	QC-03	WAUKEGAN RIVER	WASHINGTON PK WAUKEGAN	LAKE	42.357020	-87.835330
	QF-02	KELLOGG CREEK	N OF 17TH ST, 0.8 MI E OF SHERIDAN RD IN ZION	LAKE	42.464731	-87.811469

Table 2. Fish sampling station information for 2016 Lake Michigan Basin Survey, with date gear and station dimensions.

EPA STATION CODE	DNR ID	STREAM	SAMPLING DATE	SAMPLING GEAR	SAMPLE TIME (min.)	STATION LENGTH (ft.)	STATION WIDTH (ft.)
HCCB-13	17017	WEST FORK N BR CHICAGO RIIVER	8/1/2016	ES	32	500	25
HCCC-06	17015	MIDDLE FORK N BR CHICAGO RIVER	8/10/2016	ES	50	504	22
HCCC-08	17016	MIDDLE FORK N BR CHICAGO RIVER	8/15/2016	ES	30	680	71
HCCD-09	17018	SKOKIE RIVER	8/9/2016	PE	30	690	62
HCCA-02	17014	NORTH SHORE CHANNEL	6/28/2016	BE	30	1700	90
HCCA-04	17013	NORTH SHORE CHANNEL	6/28/2016	BE	30	1500	95
HCC-02	17027	NORTH BRANCH CHICAGO RIVER	9/28/2016	BE	30	1500	105
HCC-04	17026	NORTH BRANCH CHICAGO RIVER	9/28/2016	ES	32	500	25
HC-02	17029	SOUTH BRANCH CHICAGO RIVER	6/20/2016	BE	30	2000	225
HA-04	17021	LITTLE CALUMET	6/30/2016	BE	30	2000	350
HB-01	17028	LITTLE CALUMET	6/20/2016	BE	30	2000	190
HBD-05	17023	THORN CREEK	8/8/2016	ES	35	465	30
HBDA-01	17022	NORTH CREEK	8/8/2016	ES	35	510	23
HBDB-03	17024	BUTTERFIELD CREEK	8/9/2016	ES	35	650	38
HF-01	17025	TINLEY CREEK	9/9/2016	ES	45	750	45
QC-03	17019	WAUKEGAN RIVER	8/11/2016	PE	24	330	13
QF-02	17020	KELLOGG CREEK	8/11/2016	ES	20	300	10

Table 3. Native and non-native fish species captured at all 17 stations for the 2016 Lake Michiigan Basin Sruvey; all methods combined, including family, common and, scientific names, total number collected, and number of sites where each species was found.

Family Name	Common Name	Scientific Name	Total No.	Sites
Clupeidae	Gizzard shad	Dorosoma cepedianum	227	12
Umbridae	Central mudminnow	Umbra limi	132	4
Esocidae	Grass pickerel	Esox americanus	7	1
	Northern pike	Esox lucius	1	1
Cyprinidae	Goldfish**	Carassius auratus	8	4
	Common carp**	Cyprinus carpio	213	13
	Golden shiner	Notemigonus crysoleucas	103	8
	Creek chub	Semotilus atromaculatus	386	5
	Central stoneroller	Campostoma anomalum	129	3
	Spotfin shiner	Cyprinella spiloptera	5	1
	Fathead minnow	Pimephales promelas	26	5
	Bluntnose minnow	Pimephales notatus	143	10
	Emerald shiner	Notropis atherinoides	9	4
	Bigmouth shiner	Notropis dorsalis	15	3
	Sand shiner	Notropis ludibundus	13	2
Catostomidae	White sucker	Catostomus commersoni	189	14
Ictaluridae	Channel catfish	Ictalurus punctatus	3	3
	Yellow bullhead	Ameiurus natalis	49	9
	Black bullhead	Ameiurus melas	8	4
	Brown bullhead	Ameiurus nebulosus	1	1
	Tadpole madtom	Noturus gyrinus	1	1
Cyprinidontidae	Banded killifish *	Fundulus diaphanus	9	3
	Blackstripe topminnow	Fundulus notatus	275	4
Atherinidae	Brook stickleback	Culaea inconstans	4	1
	White bass	Morone chrysops	3	1
	Yellow bass	Morone mississippiensis	1	1
Centrachidae	Black crappie	Pomoxis nigromaculatus	1	1
	Rock bass	Ambloplites rupestris	4	2
	Largemouth bass	Micropterus salmoides	97	13
	Green sunfish	Lepomis cyanellus	211	10
	Bluegill x Green sunfish hybrid	Lepomis macrochirus x L. cyanellus	4	3
	Bluegill	Lepomis macrochirus	229	13
	Pumpkinseed	Lepomis gibbosus	45	7
Percidae	Yellow perch	Perca flavescens	3	2
	Johnny darter	Etheostoma nigrum	94	5
Cobitidae	Oriental weatherfish**	Misgurnus anguillicaudatus	2	2
Gobiidae	Round goby**	Neogobius melanostomus	75	4
		Total fish	2725	
		Total species	36	
		Native fish species	32	

*State Threatened; **non-native

Table 4. Fish species collected in each Lake Michigan Basin Survey, indicating number of species and sampling stations.

Common name	2001	2006	2011	2016
Bowfin	X			
Gizzard shad	X	X	X	X
Central mudminnow	X	X	X	X
Grass pickerel	X	X	X	X
Northern pike		X	X	X
Goldfish*	X	X	X	X
Common carp*	X	X	X	X
Golden shiner	X	X	X	X
Creek chub	X	X	X	X
Horneyhead chub			X	
Central stoneroller	X	X	X	X
Common shiner			X	
Spotfin shiner		X	X	X
Fathead minnow	X	X	X	X
Bluntnose minnow	X	X	X	X
Emerald shiner	X	X	X	X
Bigmouth shiner	X	X	X	X
Sand shiner		X	X	X
Spottail shiner		X		
White sucker	X	X	X	X
Channel catfish	X	X	X	X
Yellow bullhead	X	X	X	X
Black bullhead	X	X	X	X
Brown bullhead				X
Tadpole madtom				X
Banded killifish			X	X
Blackstripe topminnow	X	X	X	X
Mosquitofish	X		X	
Brook silverside			X	X
White bass			X	X
Yellow bass		X	X	X
White perch*	X	X	X	
Black crappie	X		X	X
Rock bass		X	X	X
Largemouth bass	X	X	X	X
Smallmouth bass	X		X	
Warmouth	X		X	
Green sunfish	X	X	X	X
Bluegill	X	X	X	X
Pumpkinseed		X	X	X
Orangespotted sunfish	X	X	X	
Yellow perch				X
Walleye	X			
Blackside darter			X	
Johnny darter	X	X	X	X
Iowa darter			X	
Oriental weatherfish*			X	X
Round goby*	X	X	X	X
Total no. species	30	31	42	36
Total no. native species	4	4	5	4
No. stations sampled	11	16	19	17
*Non-native fish speices				

Table 5. Fish collection results for the 2016 Lake Michigan Basin, Chicago River Sub-basin: North Shore Channel, North Branch, and South Branch; downstream of West River Park Dam. Includes total number of individuals collected for each species at each station, number of stations where each species was collected.

		North Shore Channel	North Shore Channel	N. Br. Chicago River	N. Br. Chicago River	S. Br. Chicago River
		Peterson Ave	Oakton St	North Ave	Wilson Ave	Loomis St
Common name	Total	HCCA-04	HCCA-02	HCC-04	HCC-02	HC-02
Gizzard shad	114	68	18	24	4	0
Central mudminnow	2	0	0	0	0	2
Northern pike	1	0	0	0	1	0
Carp	95	43	16	32	1	3
Golden shiner	83	13	1	3	52	14
Fathead minnow	13	0	8	0	0	5
Bluntnose minnow	6	0	2	1	0	3
Emerald shiner	9	4	2	1	2	0
White sucker	42	1	18	7	2	14
Channel catfish	2	0	1	0	1	0
Yellow bullhead	2	0	0	0	2	0
Black bullhead	1	0	1	0	0	0
Banded killifish	1	0	1	0	0	0
Rock bass	4	0	0	0	3	1
Largemouth bass	38	19	2	1	16	0
Bluegill	37	31	1	2	3	0
Pumpkinseed	12	2	0	3	5	2
Yellow perch	1	0	0	0	1	0
Oriental weatherfish	1	0	0	0	1	0
Round goby	2	0	1	0	1	0
Total fish	1153	176	380	128	288	181
Total species	21	8	15	9	13	8

Table 6. Fish collections results for the 2016 Lake Michigan Basin, Chicago River-Upstream Sub-basin: all stations upstream of West River Park Dam; total number of individuals and number of each fish species collected at each station.

Common name	Total	Mid. Fk. N. Br. Chicago River	Mid. Fk. N. Br. Chicago River	W. Fk. N. Br. Chicago River	Skokie River
Common name	Total	HCCC-06	HCCC-08	HCCB-13	HCCD-09
Gizzard shad	23	10	1	1	11
Central mudminnow	27	27	0	0	0
Goldfish	3	0	1	2	0
Carp	13	5	6	2	0
Golden shiner	18	13	5	0	0
Fathead minnow	1	0	1	0	0
Bluntnose minnow	2	2	0	0	0
White sucker	70	0	42	27	1
Yellow bullhead	7	3	1	0	3
Black bullhead	4	4	0	0	0
Tadpole madtom	1	0	0	0	1
Blackstripe topminnow	261	255	5	0	1
Black crappie	1	0	1	0	0
Largemouth bass	36	17	12	5	2
Green sunfish	84	16	9	44	15
Bluegill x Green sunfish hybrid	3	0	0	1	2
Bluegill	159	46	30	37	46
Johnny darter	1	1	0	0	0
Species	17	12	12	7	8
Total fish	714	399	114	119	82

Table 7. Fish species collected downstream of West River Park Dam by Asian Carp Monitoring Program, 2011 to 2015; North Shore Channel and lower North Branch of the Chicago River.

Common Name	Total No.
Spotfin shiner	5156
Emerald shiner	3047
Brook silverside	2248
Smallmouth bass	1132
Yellow perch	914
Rock bass	848
Banded killifish	694
Channel catfish	505
Spottail shiner	503
Freshwater drum	495
White bass	182
Smallmouth buffalo	174
Brown bullhead	122
Creek chub	118
Black buffalo	115
White crappie	82
River carpsucker	52
Quillback	50
Bigmouth buffalo	40
Bowfin	23
Warmouth	22
Grass pickerel	17
Sand shiner	16
Silver redhorse	13
Golden redhorse	7
Spotted sucker	6
Mimic shiner	5
Skipjack herring	4
Flathead catfish	3
Ghost shiner	3
Redear sunfish	3
Central stoneroller	1
Logperch	1
Longnose gar	1
Mottled sculpin	1
Shorthead redhorse	1
Spotted gar	1

Table 8. Index of Biotic Integrity (IBI) scores for the 2016 Lake Michigan Basin, Chicago River sub-basin. Includes indiviual metric values and scores. (Range 0 to 60 points, higher score indicates higher quality).

	North Shore Channel		North Shore Channel		N. Br. Chicago River		N. Br. Chicago RRiver		S. Br. Chicago River		Mid. Fk. N. Br. Chicago River		Mid. Fk. N. Br. Chicago River		W. Fk. N. Br. Chicago River		Skokie River	
	Peterson Ave		Oakton St		North Ave		Wilson Ave		Loomin Ave		Northbrook		Glenview		Deerfield		Northfield	
	HCCA-04		HCCA-02		HCC-04		HCC-02		HC-02		HCCC-06		HCCC-08		HCCB-13		HCCD-09	
IBI Metric	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score
No. fish species	7	1	12	2	8	1	11	2	7	1	11	2	10	2	5	1	8	1
No. native minnow species	5	2	2	2	3	2	4	3	5	2	5	1	2	2	0	0	0	0
No. sucker species	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	2	1	1
No. sunfish species	2	2	4	4	3	3	2	2	3	3	3	5	4	4	3	5	3	4
No. benthic invertevore species	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1
No. intolerant species	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prop. specialist benthic invertivores	0	0	0	0	0	0	0	0	0	0	0.003	1	0	0	0	0	0.012	1
Prop. generalist feeders	0.886	2	0.684	4	0.932	1	0.917	2	0.862	2	0.248	6	0.842	2	0.95	1	0.927	1
Prop. Lithophilic spawners	0.023	1	0.032	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prop. Tolerant species	0.714	2	0.333	5	0.5	4	0.455	4	0.429	4	0.455	4	0.7	2	0.8	2	0.375	4
Total IBI Score		11		19		12		14		13		20		13		11		13

Table 9. Summary of fish collections for the Lake Michigan Basin, Calumet River Sub-basin with total number of individuals collected for each species at each station.

Common name	Total	Little Calumet River HA-04	Little Calumet River HB-01	Thorn Creek HBD-05	North Creek HBDA-01	Butterfield Creek HBDB-03	Tinley Creek HF-01
Gizzard shad	90	4	70	0	13	3	0
Grass pickerel	7	0	0	0	7	0	0
Goldfish	5	4	1	0	0	0	0
Common carp	105	5	95	3	1	0	1
Golden shiner	2	2	0	0	0	0	0
Creek chub	283	0	0	201	0	34	48
Central stoneroller	129	0	0	9	0	37	83
Spotfin shiner	5	0	0	0	5	0	0
Fathead minnow	12	10	0	2	0	0	0
Bluntnose minnow	131	5	0	54	7	25	40
Bigmouth shiner	7	0	0	4	0	3	0
Sand shiner	6	0	0	0	0	6	0
White sucker	61	2	0	30	0	15	14
Channel catfish	1	0	1	0	0	0	0
Yellow bullhead	40	3	1	8	27	1	0
Black bullhead	2	0	2	0	0	0	0
Brown bullhead	1	1	0	0	0	0	0
Banded killifish	5	5	0	0	0	0	0
Blackstripe topminnow	14	0	0	0	14	0	0
White bass	3	0	3	0	0	0	0
Yellow bass	1	0	1	0	0	0	0
Largemouth bass	23	3	1	3	13	0	3
Green sunfish	103	0	0	43	3	2	55
Bluegill x Green sunfish hyb.	1	0	0	0	0	0	1
Bluegill	30	13	0	1	0	14	2
Pumpkinseed	33	18	1	0	0	14	0
Yellow perch	2	2	0	0	0	0	0
Johnny darter	93	0	0	46	1	22	24
Oriental weatherfish	1	0	0	0	0	1	0
Round goby	73	0	0	0	46	27	0
Species	29	14	10	12	11	14	9
Total fish	1269	77	176	404	137	204	271

Table 10. Index of Biotic Integrity (IBI) scores for the 2016 Lake Michigan Basin,Calumet River sub-basin. Includes individual metric values and scores. (Range 0 to 60 points, higher score indicates higher quality).

	Little		Little		Thorn		North		Butterfield		Tinley	
	HA-04		HB-01		HBD-05		HBDA-01		HBDB-03		HF-01	
IBI Metric	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score
No. fish species	12	2	8	1	11	2	9	2	12	2	8	1
No. native minnow species	5	2	0	0	5	3	2	1	5	3	3	2
No. sucker species	1	1	0	0	1	2	0	0	1	1	1	1
No. sunfish species	3	3	2	2	3	5	2	4	3	4	3	4
No. benthic invertevore species	0	0	0	0	2	2	1	1	2	2	1	1
No. intolerant species	0	0	0	0	0	0	0	0	0	0	0	0
Prop. specialist benthic invertivores	0	0	0	0	0.114	4	0.007	1	0.108	4	0.089	3
Prop. generalist feeders	0.636	5	0.966	1	0.856	2	0.409	6	0.505	6	0.59	6
Prop. Lithophilic spawners	0	0	0	0	0.022	1	0	0	0.181	3	0.306	4
Prop. Tolerant species	0.583	3	0.375	4	0.636	3	0.444	4	0.417	4	0.625	3
Total IBI Score		16		8		24		19		29		25

Table 11. Fish collections for the Lake Michigan Basin, direct tributaries to Lake Michigan, with total number of individuals collected for each species at each station.

		Waukegon River	Kellog Creek
	Total	QC-03	QF-02
Central mudminnow	103	2	101
Creek chub	103	1	102
Bluntnose minnow	4	0	4
Bigmouth shiner	8	0	8
Sand shiner	7	0	7
White sucker	16	6	10
Black bullhead	1	1	0
Banded killifish	3	0	3
Brook stickleback	4	0	4
Green sunfish	24	22	2
Bluegill	3	3	0
Species	11	6	9
Total fish	276	35	241

Table 12. Index of Biotic Integrity (IBI) scores for the 2016 Lake Michigan Basin, Direct Tributaries. Includes individual metric values and scores. (Range 0 to 60 points, higher score indicates higher quality).

	Waukegon River		Kellogg Creek	
	QC-03		QF-02	
IBI Metric	Value	Score	Value	Score
No. fish species	6	1	9	2
No. native minnow species	1	1	4	2
No. sucker species	1	3	1	3
No. sunfish species	2	5	1	3
No. benthic invertevore species	0	0	1	1
No. intolerant species	0	0	0	0
Prop. specialist benthic invertivores	0	0	0	0
Prop. generalist feeders	0.943	1	0.552	6
Prop. Lithophilic spawners	0	0	0	0
Prop. Tolerant species	0.5	4	0.444	4
Total IBI Score		20		21

Table 13. Index of Biotic Integrity (IBI) Lake Michigan Basin Survey, all stations 2001 to 2016.

		IBI			
Stream	Code	2001	2006	2011	2016
West Fk N Br Chgo River	HCCB-13		9	12	20
Mid Fk N Br Chgo River	HCCC-06		19	24	13
Mid Fk N Br Chgo River	HCCC-08			15	11
Skokie River	HCCD-09	19	20	17	13
North Shore Channel	HCCA-02		22	16	11
North Shore Channel	HCCA-04	12	14	16	19
North Branch Chicago River	HCC-02		11	19	12
North Branch Chicago River	HCC-04			19	14
South Branch Chicago River	HC-02			18	13
Little Calumet River	HA-04	19	20	22	16
Little Calumet River	HB-01	12	15	15	8
Thorn Creek	HBD-05	11	13	17	24
North Creek	HBDA-01	22	17	26	19
Butterfield Creek	HBDB-03	20	25	28	29
Tinley Creek	HF-01	25	24	24	25
Waukegon River	QC-02			14	20
Keliogg Creek	QF-02			20	21
	mean	17.5	17.4	18.9	16.9
	sd	4.87	4.58	4.07	5.78

Table 14. Sportfish total catch rate (no./hour) for the Lake Michigan Basin Survey, 2001-2016.

Sub-basin	Species	2001	2006	2011	2016
Chicago River sub-basin	Largemouth bass	45.0	23.0	16.8	15
	Bluegill	25.0	31.1	49	41
Calumet River sub-basin	Largemouth bass	12.2	13.8	25	7
	Bluegill	9.2	6.9	16.8	9