Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago

MONITORING AND RESEARCH DEPARTMENT

REPORT NO. 18-24

ASSESSMENT OF SOUTH BRANCH CHICAGO RIVER SLIPS USING BIOLOGICAL SAMPLING, HABITAT, SEDIMENT CHEMISTRY, AND DISSOLVED OXYGEN PROFILING DATA BETWEEN 2013 AND 2015

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LIST OF ABBREVIATIONS

Abbreviation/Acronym	Definition
ANOVA	analysis of variance
Ashland Avenue	Ashland Avenue on the South Branch Chicago River
CAWS	Chicago Area Waterway System
CAWSHI	Chicago Area Waterway System habitat index
COC	chemicals of concern
CPUE	catch per unit effort
CSOs	combined sewer overflows
Damen Avenue	Damen Avenue on the Chicago Sanitary and Ship Canal
District	Metropolitan Water Reclamation District of Greater Chicago
DO	dissolved oxygen
GPP	generator-powered pulsator
HD	Hester Dendy
IBI	index of biotic integrity
IEPA	Illinois Environmental Protection Agency
K-S	Kolmogorov-Smirnov
Loomis Street	Loomis Street on the Chicago Sanitary and Ship Canal
NH_3-N	ammonia nitrogen
$NO_2 + NO_3$	nitrite plus nitrate nitrogen
OPPs	organic priority pollutants
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PEC	probable effect concentration
PP	Petite Ponar grab sampler
SBCR	South Branch Chicago River
SBCRS	South Branch Chicago River Slips
SOD	sediment oxygen demand
SQGs	sediment quality guidelines
TARP	Tunnel and Reservoir Plan
TCN	total cyanide
TEC	threshold effect concentration
TKN	total Kjeldahl nitrogen
TP	total phosphorus
TS	total solids
TVS	total volatile solids
USEPA	United States Environmental Protection Agency
WRP	water reclamation plant

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DISCLAIMER

Mention of proprietary equipment and chemicals in this report does not constitute endorsement by the Metropolitan Water Reclamation District of Greater Chicago.

SUMMARY AND CONCLUSIONS

Description of the Study

The Metropolitan Water Reclamation District of Greater Chicago (District) service area waterways consist of manmade canals and natural streams which have been altered to varying degrees. Some natural waterways have been deepened, straightened, and/or widened. The South Branch Chicago River (SBCR) contains manmade off-channel waterways referred to as slips. Slips in the SBCR were created to distribute lumber in the heart of the lumber district in the 1850's through the end of the 19th century. In their present state, the SBCR slips provide refuge for fish from main channel commercial barge and recreational boat traffic. This study was conducted between 2013 and 2015 to assess the habitat, dissolved oxygen (DO) concentrations during normal and wet weather conditions, fish abundance and species richness, and sediment quality in Arnold's Slip, Stetson's Slip, and Mason's Slip, from here on referred to as the SCBR slips (SBCRS). The goal of the study was to determine which areas of the SBCRS were used most heavily by aquatic life and the factors affecting this use. If less productive areas were found, the study also sought to assess what habitat attributes could be modified or added to make slips more useful to fish.

Significant Findings

Overall, the SBCRS had a number of habitat features that were found by LimnoTech (2010) to be negatively associated with Chicago Area Waterway System (CAWS) fish data. The SBCRS had very steep banks with over 90 percent of the banks having vertical or near vertical walls, and no aquatic macrophytes were observed. Silt was the dominant substrate throughout the SBCRS. Arnold's Slip had the highest amount of fine sediments with a maximum depth of fines of 2.5 meters. Most of the SBCRS sediments had concentrations of metals and polycyclic aromatic hydrocarbons (PAHs) that are known to have adverse effects on sediment-dwelling organisms. However, the SBCRS had some features that contributed to the quality of refuge for fish and other biota. Overall, the SBCRS were shallower than the main channel of the SBCR. Arnold's and Stetson's Slips provided some overhanging vegetation, which is sparse in the CAWS. Stetson's Slip provided the most refuge type habitat, because it was the longest slip with the smallest percentage of constructed vertical wall banks and it has several hidden bank pockets along the water's edge, although they were mostly only visible when water levels were drawn down to accommodate rain events.

Despite having areas of fine sediments containing elevated concentrations of metals and PAHs, live freshwater mussels were found in three different areas within Stetson's Slip during a wet weather cross-sectional sampling event (September 20, 2013). A total of 10 live (including two juveniles) *Pyganodon grandis* (giant floater) were found out of the water or in shallow water near the shoreline. The presence of juveniles suggests that the population could be sustainable. Giant floaters are native to Illinois and are typically found in ponds, lakes, or sluggish muddy substrates and thrive in impoundments and are tolerant to sedimentation and pollution (Cummings and Cordeiro, 2012), which qualifies the SBCRS as suitable habitat for this species.

Between 2013 and 2015, 15.5 hours of electrofishing yielded 7,197 fish, with a total catch weight of 600.5 kilograms, in the SBCRS. A total of 34 fish species, including 14 game species, one state threatened species, and three hybrid species were collected from the SBCRS. More than half of the fish collected were collected in Stetson's Slip. Statistical analysis of catch per unit effort (CPUE) data for mean total number of fish per hour, game fish, and largemouth bass yielded no significant differences among the SBCRS. However, Stetson's Slip had the highest mean CPUE of total fish (482 fish/hour), game fish (213 fish/hour), and largemouth bass (34 fish/hour). Stetson's Slip also had the highest cumulative number of fish species (30), collected between 2013 and 2015.

Mean DO concentrations yielded interesting results, because mean DO concentrations in Stetson's Slip were significantly lower than the other slips during seasonal dry conditions. During wet weather events, mean DO concentrations were significantly lower in Arnold's Slip (3.8 mg/L) than Mason's Slip (4.3 mg/L) but not Stetson's Slip (4.1 mg/L). Wet weather event sampling was completed within 24 hours of Racine Avenue Pump Station (RAPS) discharge. Arnold's Slip is located directly across the river from the South Fork SBCR (Bubbly Creek) and RAPS is located at the southern end of Bubbly Creek. When RAPS is active, combined sewer flows from the pump station and travels north into the SBCR and likely into Arnold's Slip. Arnold's Slip had the lowest mean DO concentrations after wet weather events. In addition, mean DO concentrations in the middle and end transects of Stetson's Slip were significantly lower than the other transects during seasonal dry conditions, possibly due to the stagnant conditions that are a result of the length of the slip and possibly sediment oxygen demand (SOD). Stetson's Slip is the longest of the SBCRS and therefore has the potential to have largest reach of stagnant water. Low DO concentrations (<2 mg/L) can have an immediate impact on aquatic biota and long term impacts on biota if exposed to low DO conditions for extended periods of time.

Stetson's Slip was most heavily used by aquatic life, because it had the largest amount of fish, the largest number of fish species, the highest mean CPUE of fish, and live freshwater mussels in three separate areas. Stetson's Slip had a combination of habitat features that supported the most aquatic life among the SBCRS. Stetson's Slip is the largest slip and provided the most habitat with overhanging vegetation. Stetson's Slip was the second shallowest slip and was shallower that the main channel of the SBCR. Arnold's Slip and Mason's Slip had some of the same habitat features as Stetson's Slip but in lesser amounts or lesser quality. Arnold's and Mason's Slips would benefit from the addition of bank pocket areas, undercut banks, and instream structures or submerged structures similar to what was found in Stetson's Slip. Mason's Slip would also benefit from more protection from barge traffic. All of the biota in the SBCRS and SBCR could benefit from more littoral zones and aquatic macrophytes in the slips.

Future Study

Water quality in the CAWS has improved since the Clean Water Act, due to the District's improvements in wastewater treatment and the tunnel and reservoir plan (TARP), and the District is currently working on a number of major projects to further enhance water quality of the CAWS. As water quality improves, the CAWS could be potentially more inviting to intolerant species, but the presence and behavior of fish is not solely dependent on water quality (LimnoTech, 2010 and Gaulke et al., 2015). Fish and other aquatic biota have preferred habitats, and if that habitat is not present in a waterway, resident populations will not establish even if the water quality is optimal.

The SBCRS provide some unique areas of refuge, but it is likely that the SBCRS and other areas with similar habitats could provide more areas of refuge to biota with the installation of additional habitat features or the modification of existing features. Evaluation of other off-channel habitat areas in the CAWS could be an opportunity to find other areas that could provide much needed habitat to biota with minimal improvement to maximize economic resources. Adding more artificial habitat or improving existing habitat within off-channel areas could be a good investment, because many of these areas (or parts of them) are not used by barges and do not affect navigation and main channel conveyance capacity.

This study did not fully assess the impact of the elevated concentrations of metals and PAHs on the bottom-dwelling biota. Further assessment might be useful to determine if sediment remediation can help to improve aquatic life use in the SBCRS. Benthic invertebrates were collected but not identified for this study, and could be identified at a later date if further assessment of SBCRS sediments is desired.

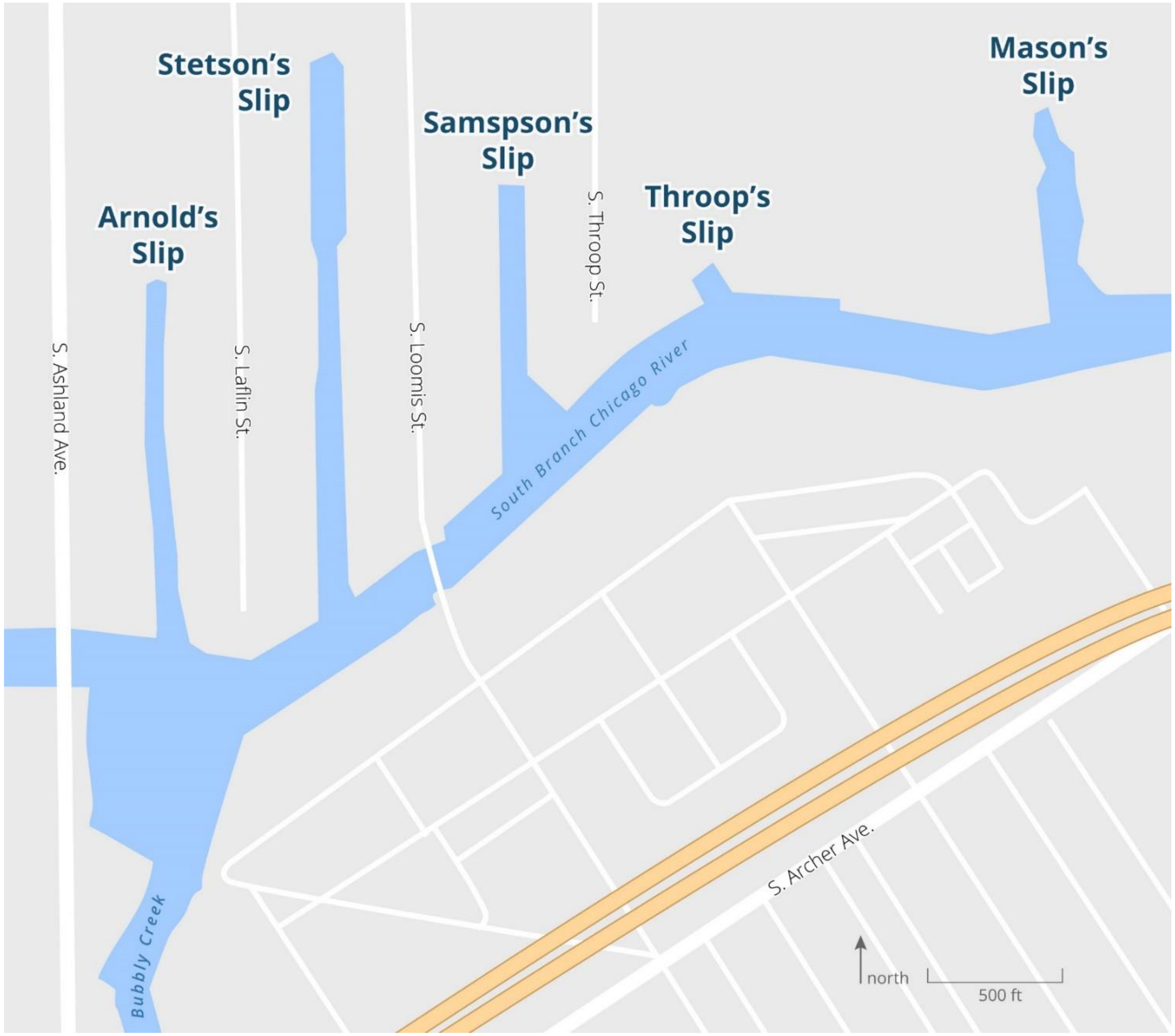
INTRODUCTION

The District service area waterways consist of manmade canals and natural streams which have been altered to varying degrees. Most of the natural waterways in the CAWS have been deepened, straightened, and/or widened. Because of these alterations, habitat is a major limiting factor in the CAWS. The SBCR is an example of a waterway that has been heavily modified by man. Bubbly Creek has a famous history of being polluted and is severely man-altered. Historically, there were up to18 manmade off-channel waterways, called slips, on the north bank of the SBCR that were created to distribute lumber in the heart of the lumber district in the 1850's through the end of the 19th century (Solzman, 2006). Over the years, many of these slips were filled in completely or partially. Currently, there are five manmade slips north and northeast of Bubbly Creek; Mason's Slip, Throop's Slip, Sampson's Slip, Stetson's Slip, and Arnold's Slip. In their present state, these slips provide refuge for fish from main channel commercial barge and recreational boat traffic, but could potentially function in some ways as backwater lakes.

LimnoTech assessed the habitat in the CAWS in 2008 and determined that off-channel bays were one of the key habitat variables that were positively associated with fish populations (LimnoTech, 2010). The SBCRS are some of the largest off-channel bays in the CAWS. In 2015, Gaulke et al. found that hypoxic events had very limited effect on the behavior of largemouth bass in the CAWS. They defined hypoxic conditions as having DO concentrations of less than 2 mg/L. The study also showed that resident largemouth bass had an improved capability of transporting oxygen to the blood when compared to reference site fish, which may be why CAWS largemouth bass were able to tolerate areas where DO concentrations were less than 2 mg/L. Personnel from the District's Aquatic Ecology and Water Quality Section (AEWQ) assisted with the field collection of largemouth bass for this study. While collecting largemouth bass in the study area within the SBCR, it was apparent early in the study that the SBCRS were the preferred habitat of largemouth bass in that area because the majority of fish that were chosen for the study came from the slips. It was also noted that Stetson's Slip was particularly productive, because repeated sampling of that slip with a boat mounted electrofisher yielded a largemouth bass that met the size requirements (224 mm to 350 mm in total length) for tracking tag implantation. Fish in this size range were large enough to survive the surgery required for the implantation of the long term telemetry devices.

This study was conducted to determine which slips are used most heavily by aquatic life and why, and how less productive slips can be modified to improve habitat for fish. This study was designed to use habitat, DO concentrations during normal and wet weather conditions, benthic invertebrate community, fish abundance and species richness, and sediment quality data to assess the SBCRS, between 2013 and 2015. A map of the study area is shown in Figure 1.

FIGURE 1: SOUTH BRANCH CHICAGO RIVER SLIPS



MATERIALS AND METHODS

Habitat assessments, sediment chemistry, benthic invertebrate, fish, and cross-sectional DO profiling events were completed to evaluate SBCR slips between 2013 and 2015. After a quick assessment of Throop's Slip using geographic information system (GIS) images, it was determined that it was too small to assess. Habitat, fish, and DO concentrations were also not assessed in Sampson's Slip, due to the restrictive amount of barge containers that occupied the slip on a consistent basis. Fish collections were completed three times a year during 2013 and 2015 and two times in 2014. A total of 12 complete DO cross-section events were completed in the SBCRS and Loomis Street on the SBCR (Loomis Street) and Ashland Avenue on the SBCR (Ashland Avenue), between 2013 and 2015. Benthic invertebrates were sampled via Hester Dendy (HD) artificial substrate samplers in 2013 and 2014 in Mason's, Stetson's, Arnold's and Sampson's slips, along with Loomis Street and Damen Avenue on the Chicago Sanitary and Ship Canal (Damen Avenue), in 2013 and 2014. Habitat assessments of the SBCRS were completed in July of 2013. Sampling dates for fish collection, habitat assessment, benthic invertebrates, DO concentration cross-sections, and sediment collection for the SBCRS, Damen stations between 2013 and 2015 are shown in Table 1.

Habitat

In 2010, LimnoTech developed the CAWS habitat index (CAWSHI) by identifying key habitat variables that best explain fish data (LimnoTech, 2010). Because slips are essentially large off-channel bays (OCBs) created to dock boats used for distributing lumber, and OCBs are a habitat variable that is used to calculate CAWSHI scores, we decided to use a select number of habitat metrics to evaluate the habitat of Arnold's, Stetson's, and Mason's slips. Data collected in the field and via GIS software (ArcMap 10.3.1) were used to calculate or quantify values for five metrics that LimnoTech used in their CAWSHI and a modified version of one of their metrics for verticle wall banks. A combination of positively and negatively correlated metrics were chosen to evaluate the habitat in the slips and the potential influence on fish communities in those slips. Maximum depth of channel, percent of vertical wall banks, percentage of riprap banks, and the number of manmade structures were variables that were chosen that had negative correlations with fish data. Macrophyte cover, and overhanging vegetation were also selected and theses features were found to have positive correlations with fish data by LimnoTech.

Methods of habitat assessment used in this study to evaluate the slips were loosely based on methods suggested in a draft LimnoTech document titled "Standard Operating Procedures for Aquatic Habitat Field Assessment within the Chicago Area Water System" (LimnoTech, 2010). Habitat assessments were completed by compiling habitat data from multiple transects within each slip and observational data that was collected throughout each slip. Transects were approximately every 100 meters of each slip with the first transect near the confluence of the SBCR main channel. Each transect consisted of five points across the width of slips; i.e. one sampling point mid-channel, two midway between the shoreline and the middle on the left and right of the mid-channel point, and two sample points 0.5 meters from the shoreline on the right and left sides of slips.

TABLE 1: COLLECTION DATES AND TYPES OF SAMPLING IN THE SOUTH BRANCH CHICAGO RIVER AND SLIPS BETWEEN 2013 AND 2015

Location(s)	Sampling Type	Date(s)
Mason's Slip	Electrofishing	06/25/13, 08/05/13, 10/10/13, 07/24/14, 09/25/14, 07/06/15, 09/25/15, 10/21/15
Stetson's Slip	Electrofishing	06/27/13, 08/01/13, 10/11/13, 06/24/14, 09/24/14, 07/10/15, 09/23/15, 10/23/15
Arnold's Slip	Electrofishing	07/01/13, 08/01/13, 10/10/13, 06/24/14, 09/24/14, 07/09/15, 09/22/15, 10/23/15
Loomis Street and Damen Avenue	Benthic Invertebrate	07/15/13, 07/02/14
Arnold's, Stetson's and Mason's Slips	Benthic Invertebrate	07/16/13, 07/03/14
Sampson's Slip	Benthic Invertebrate	08/01/13, 08/05/13
Mason's and Arnold's Slips	Habitat Assessment	07/17/13
Stetson's Slip	Habitat Assessment	07/18/13
Mason's, Stetson's and Arnold's Slips	Sediment Chemistry	05/15/14
Loomis Street, Damen Avenue, Arnold's, Stetson's and Mason's Slips	DO Cross-Sections	08/22/13, 10/17/13, 5/13/14[1], 9/19/14, 10/28/14, 06/04/15, 8/12/15,10/07/15[1], 10/30/15
Loomis Street, Damen Avenue, Arnold's, Stetson's and Mason's Slips	Wet Weather DO Cross-Sections	9/20/2013, 6/25/14[1], 9/11/14, 10/03/14, 06/15/15, 08/19/15

DO = Dissolved oxygen.
[1]Incomplete sampling event.

Total length and shoreline length of each slip was measured in ArcMap 10.3.1 and verified in the field with a range finder where possible. Banks that were completely vertical and constructed of steel, wood, and concrete were measured in ArcMap 10.3.1. Depth measurements were completed using a boat mounted depth finder and a leveling rod at each sampling point of each transect. The width of each slip was measured using a rangefinder at each transect. Depth of fines was measured using a leveling rod at each sampling point of each transect. Secchi depth was measured once per transect at the mid-channel sampling point. Sediment composition was assessed via visual inspection where collection by Petite Ponar grab sampler (PP) was possible. The predominant sediment component for each slip was identified as the component present in the highest amount at each transect throughout each slip. General observations related to aesthetics, vegetation amounts, manmade structures, riprap banks, or potential fish spawning areas in each slip were noted when applicable. Efforts were made to coordinate the enumeration of bank pocket areas that were exposed during low water conditions (such as observed on September 20, 2013) in the SBCRS but they were unsuccessful due to scheduling issues and inclement weather conditions, because water stages in the CAWS are generally drawn down to maximize stormwater storage during wet weather events.

The following are the five metrics from the CAWSHI and one additional metric (Percent Constructed Vertical Wall Banks) chosen to evaluate habitat in Mason's, Stetson's, and Arnold's slips and their definitions and how they were calculated for this study.

1. **Maximum Depth.** Maximum and mean depth of each slip were calculated using all of the depth measurements in each transect.

2. **Percent Constructed Vertical Wall Banks.** Percent constructed vertical banks is not a metric from the CAWSHI, but was a modified version of LimnoTech's percent verticle wall banks that was calculated to differentiate between banks that were constructed and completely vertical and banks that were just steep. Length of constructed vertical walls in each slip was measured in ArcMap 10.3.1. Percent constructed vertical walls was calculated as length of vertical wall divided by total length of shoreline multiplied by 100.

3. **Percentage Riprap Banks.** Riprap banks are banks that are covered with rocks or rock-like material that was used to armor a shoreline. Percentage of riprap banks was calculated almost the same as the percent vertical wall banks but using length of riprap bank instead of length of vertical wall.

4. **Number of Manmade Structures.** Manmade structures are constructed features that are present in the waterway that were placed for the purpose of human use, either currently or previously and were left in the waterway unintentionally or intentionally. Manmade structures were counted in each slip.

5. **Macrophyte Cover.** For this study, macrophytes were considered as any group of attached aquatic plants. Macrophyte cover is typically estimated in relation to the surface area of the a study area. No macrophytes were observed in the slips.

6. **Percent Overhanging Vegetation.** Overhanging vegetation consists of trees or shrubs that provide shade over a waterway and its shoreline. The percent of overhanging vegetation was calculated as the estimated amount canopy coverage observed throughout each slip divided by the estimated surface area multiplied by 100.

Sediment Chemistry

Sample Collection. Sediment samples were collected with the use of a six-inch by six-inch PP. Prior to sample collection, the PP and the metal and plastic pans and scoops used to process the materials were cleaned with hot water and laboratory detergent, rinsed with de-ionized water and allowed to air dry. The PP and metal pans and scoops were then rinsed with acetone, allowed to air dry, then dried in an oven at 105°C for one hour. After cooling, each set was placed in a plastic bag and sealed to prevent contamination until ready for use.

Sediment samples were collected from the three locations (beginning, middle, and end) in the center of Mason's, Stetson's and Arnold's slips using a separately cleaned PP at each sample location on May 15, 2014. The beginning sampling point of each slip was within the slip's banks just north of where the SBCR main channel begins. The middle sampling point of each slip was the approximate north and south middle of each slip. The end sampling point was based on individual markers for each slip. The sampling point at the end of Stetson's Slip and Mason's Slip was approximately 30 meters south of the northern end where steel sheet piling began on the west bank. Arnold's end sampling point was 35 meters south of the northern shoreline. The sediment samples were transferred into plastic or metal pans, and then put into the appropriate container using plastic or metal scoops. Metal scoops and pans were used for samples collected in glass containers. The filled sample containers were placed on ice until they could be refrigerated at four degrees Celsius.

Sample Analyses. The sediment samples were analyzed for total solids (TS), total volatile solids (TVS), ammonia nitrogen (NH_3-N), nitrite plus nitrate nitrogen ($NO_2 + NO_3$), total Kjeldahl nitrogen (TKN), total phosphorus (TP), total cyanide (TCN), phenols, total metals (including arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, and zinc), and organic priority pollutants (OPPs) (listed in Table 2) by the District's Analytical Laboratory Division. Sediment samples were collected and stored in glass containers. In the laboratory, all constituents were analyzed using procedures established by the United States Environmental Protection Agency (USEPA, 2001) or described in *Standard Methods for the Examination of Water and Wastewater* (22^{nd} Edition, 2012).

Benthic Invertebrates

Artificial Substrate Sampling. HD artificial substrate samplers were deployed at two locations in each slip and two main channel locations between June 2013 and May in 2014. Figure 2 shows the plate configuration of the HD sampler assembled prior to deployment in the

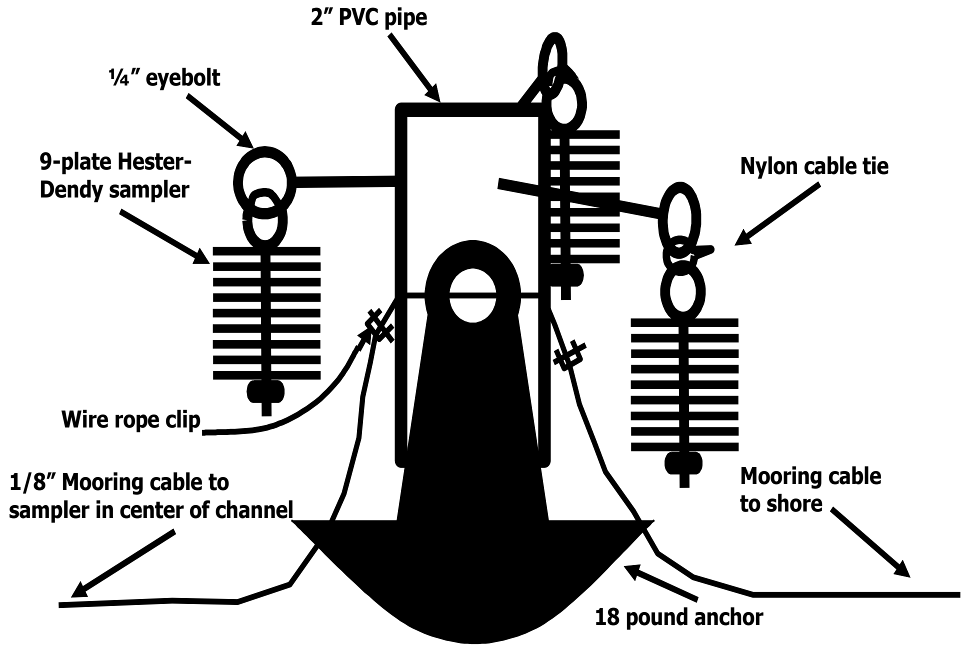
TABLE 2: LIST OF ORGANIC PRIORITY POLLUTANTS ANALYZED IN SEDIMENT SAMPLES COLLECTED FROM SOUTH BRANCH CHICAGO RIVER SLIPS ON MAY 15, 2014

Volatile Organic Compounds	Acid Extractables	Base/Neutral Extractables	Pesticides and PCBs
Acrolein	2-Chlorophenol	Acenaphthene	Aldrin
Acrylonitrile	2,4-Dichlorophenol	Acenaphthylene	alpha-BHC
Benzene	2,4-Dimethylphenol	Anthracene	beta-BHC
Bromoform	4,6-Dinitro-o-cresol	Benzidine	gamma-BHC
Carbon tetrachloride	2,4-Dinitrophenol	Benzo(a)anthracene	delta-BHC
Chlorobenzene	2-Nitrophenol	Benzo(a)pyrene	Chlordane
Chlorodibromomethane	4-Nitrophenol	3,4-Benzofluoranthene	4,4'-DDT
Chloroethane	Parachlorometacresol	Benzo(ghi)perylene	4,4'-DDE
2-Chloroethylvinyl ether	Pentachlorophenol	Benzo(k)fluoranthene	4,4'-DDD
Chloroform	Phenol	Bis(2-chloroethoxy)methane	Dieldrin
1,2 – Dichlorobenzene	2,4,6-Trichlorophenol	Bis(2-chloroethyl)ether	Endosulfan-I
1,3 – Dichlorobenzene		Bis(2-chloroisopropyl)ether	Endosulfan-II
1,4-Dichlorobenzene		Bis(2-ethylhexyl)phthalate	Endosulfan sulfate
Dichlorobromomethane		4-Bromophenyl phenyl ether	Endrin
1,1-Dichloroethane		Butylbenzyl phthalate	Endrin aldehyde
1,2-Dichloroethane		2-Chloronaphthalene	Heptachlor
1,1-Dichloroethylene		4-Chlorophenyl phenyl ether	Heptachlor epoxide
1,2-Dichloropropane		Chrysene	PCB-1242
1,3-Dichloropropene		Dibenzo(a,h)anthracene	PCB-1254
Ethyl benzene		3,3-Dichlorobenzidine	PCB-1221
Methyl bromide		Diethyl phthalate	PCB-1232
Methyl chloride		Dimethyl phthalate	PCB-1248
Methylene chloride		Di-n-butyl phthalate	PCB-1260
1,1,2,2-Tetrachloroethane		2,4-Dinitrotoluene	PCB-1016
Tetrachloroethylene		2,6-Dinitrotoluene	Toxaphene
Toluene		Di-n-octyl phthalate	

TABLE 2 (Continued): LIST OF ORGANIC PRIORITY POLLUTANTS ANALYZED IN SEDIMENT SAMPLES COLLECTED FROM SOUTH BRANCH CHICAGO RIVER SLIPS ON MAY 15, 2014

Volatile Organic Compounds	Acid Extractables	Base/Neutral Extractables	Pesticides and PCBs
1,2-trans-Dichloroethylene		1,2-Diphenylhydrazine	
1,1,1-Trichloroethane		Fluoranthene	
1,1,2-Trichloroethane		Fluorene	
Trichloroethylene		Hexachlorobenzene	
Vinyl chloride		Hexachlorobutadiene	
Trichlorofluoromethane		Hexachlorocyclopentadiene	
		Hexachloroethane	
		Indeno(1,2,3-cd)pyrene	
		Isophorone	
		Naphthalene	
		Nitrobenzene	
		N-Nitrosodimethylamine	
		N-Nitrosodi-n-propylamine	
		N-Nitrosodiphenylamine	
		Phenanthrene	
		Pyrene	
		1,2,4-Trichlorobenzene	

FIGURE 2: CONFIGURATION OF HESTER DENDY LARVAL PLATE SAMPLER



waterways. A total of 27 three-inch by three-inch sampling plates were attached to each 18-pound river anchor, connected to an object on shore (usually a tree). Two HD assemblies were tethered to another by a cable and were then placed on the bottom of the waterway, one in the center and the other on one side at Loomis Street and Damen Avenue. Loomis Street and Damen Avenue were chosen because recent benthic invertebrate data were available for comparison. Single HD assemblies were deployed in the slips. The locations of HD assemblies in the slips were as evenly spaced throughout each slip as possible where suitable inconspicuous attachment areas were available. The targeted amount of time for HD assemblies to be left in the waterway was six weeks. The HD samplers were located, and the anchors were lifted out of the waterway with a 250 µm mesh plankton net underneath to avoid organism loss at the water surface. The plates were then cut from the anchors and placed into a one-gallon bucket with a secure, leak-proof lid. Invertebrates from the plankton net reservoir were also rinsed into the buckets, which were then filled with river water and brought to a 10 percent final concentration of formalin. These samples were then brought to the laboratory and stored at 4°C until processed.

Benthic Invertebrate Processing. Samples were fixed in formalin for at least thirty days. Next, each HD plate was removed from the sampler and gently brushed with a paintbrush on both sides while under a slow stream of running water in order to rinse the attached invertebrates into the sieve. The formalin solution remaining in the HD sample container was rinsed into the sieve in order to capture any invertebrates that fell from the HD plates. The contents of this sieve were then rinsed back into the bucket with a 70 percent ethanol solution. The PP and HD samples were then stored at 4°C until further processed. Before processing, the samples were sieved to remove the ethanol solution. The sieved material was then examined in small batches under a compound microscope in a 100 mm by 50 mm glass crystallizing dish filled about one cm high. We then counted oligochaete worms and removed all other invertebrates from the finer residual material. In situations where large numbers (>3,000) of any one taxon (usually worms) were encountered, their abundance was estimated using a sub-sampling device.

Fish

Before each fishing event in each slip, ambient weather conditions, water temperature, DO concentration, specific conductivity and Secchi depth were recorded on field data sheets. Fish were collected in each slip using a boat mounted Smith-Root 5.0 generator-powered pulsator (GPP) electrofisher set to apply pulsed direct current (DC) into the water at 120 pulses per second and a target output of about 14 amperes. Stunned fish were picked out of the water with long-handled dip nets. The entire shorelines of Arnold's and Mason's slips were sampled in one continuous haul for each slip, during each sampling event. Because Stetson's Slip relatively large and yielded many fish, the entire shoreline was split in half (east side and west side) and sampled in two hauls per sampling event. Only two sampling events were completed in 2014, because of mechanical issues with the generator that powered the boat mounted electrofisher.

Fish Processing. In the field, most fish were identified to species, weighed to the nearest gram or nearest 0.1 gram (depending on size), measured for standard and total length to the nearest millimeter, and examined for the incidence of disease, parasites, or other anomalies. Following processing, these fish were returned live to the river. Minnows and other small fish that were difficult to identify were preserved in a 10 percent formalin solution and returned to the laboratory for further analysis. These fish were processed in a similar manner to the field-measured fish except that they were weighed to the nearest 0.01 gram.

Index of Biotic Integrity. Biological integrity of aquatic ecosystems is the ability to support and maintain a balanced, integrated, and adaptive community having a species composition, diversity, and functional organization comparable to that of a natural habitat (Karr et al., 1986). Karr's 1986 index of biotic integrity (IBI) was used to analyze fish data.

The limitations of using this tool to assess man-made and large channelized waterways in the Chicago area should be recognized, because this index was designed to measure the integrity of small wadeable streams. Karr's IBI integrates information from 12 fish community metrics that fall into three major categories: (1) species richness and composition, (2) trophic composition, and (3) fish abundance and condition. Each metric is scored 1, 3, or 5 based on whether its evaluation deviates strongly, deviates somewhat, or approximates expectations, respectively, as compared to an undisturbed site located in a similar geographical region and on a stream of comparable size. Individual metrics are added to calculate a total IBI score. A high IBI indicates high biological integrity or health and low disturbance or lack of perturbations. A low IBI indicates low biological integrity and high disturbance or degradation. Separate IBI metric scores were determined based on the relative abundance of fish collected with each fishing gear, but only IBI scores calculated from electrofishing methods are discussed in this report. IBI categories of Good (41–60), Fair (21–40), or Poor (<21) were determined, as derived by the Illinois Environmental Protection Agency (IEPA, 1996).

Statistical Analyses of Fish Abundance. CPUE, defined as number of fish collected per hour, was calculated for each sampling event for each slip. single factor (one way) analysis of variance (ANOVA) of CPUE data using Microsoft Excel was done to determine if the mean CPUE of each slip was significantly different.

Dissolved Oxygen Cross-Sectional Profiling

Starting in the summer of 2013, cross-sectional DO surveys were conducted seasonally. Cross-sectional DO surveys were completed in the spring, summer, and fall through 2015 in Mason's, Stetson's and Arnold's slips as well as Loomis Street and Ashland Avenue. Cross-sectional DO profiling was also performed within 24 hours of the end of wet weather events in which RAPS actively pumped combined sewage into Bubbly Creek, when possible. Wet weather DO profiling was performed to determine if the SBCRS DO concentrations were heavily influenced by wet weather and to what extent they were affected.

DO concentrations were measured directly with a monitor at three locations and multiple depths across the waterway. Cross-sectional DO measurements were taken in the center, right, and left sides, facing the direction of the flow in the main channel at Loomis Street and Ashland Avenue, and facing north in the slips from a boat. DO profiling was completed at three transects in each slip per event (beginning, middle, and end) at the same locations that sediment was collected. DO profiling was completed at only one transect at each of the main channel locations per event. DO measurements were recorded at up to four depths for each location, including just above the bottom of the stream bed, one-half the total depth, three feet below the surface, and at the surface. If the overall depth was less than eight feet, then the one-half depth measurement was not recorded. If the overall depth was less than four feet, only bottom and surface measurements were recorded, and if the overall depth was less than one foot, only a surface measurement was recorded.

Statistical Analyses of Dissolved Oxygen Profiling Data. DO data from complete seasonal and wet weather cross-sectional profiling events were compiled for statistical analysis. Statistical significance was tested between: (1) mean DO concentrations of SBCRS and Ashland Avenue and Loomis Street, (2) right, left, and center locations within transects of the SBCRS, (3) transects within each each of the SBCRS, and (4) between SBCRS transects and Ashland Avenue and Loomis Street, during dry seasonal and wet weather conditions. Statistical analysis of cross-sectional DO data was completed by using the ANOVA method. To validate ANOVA methodology, we first assumed normality of data. Otherwise, we tested the normality via the Kolmogorov-Smirnov (K-S) method and found the data to be normal in each level in every situation. The homogeneity of variances in two levels were verified by F-test, and by Levene's or modified Levene's test was used if the test involved more than two levels. We performed one-way ANOVA for two or more levels. If the ANOVA test showed level means were significantly different, Scheffe's or Tukey's multiple comparison tests were performed between the two possible levels. If Levene's test showed that standard deviations were not equal, then no ANOVA was performed. Instead, multiple comparison tests were performed between two possible levels using a modified T-test. If the data had only two levels, we performed ANOVA using T-test or modified T-test which ever was applicable.

RESULTS

Habitat

A summary of the habitat data that was collected and calculated habitat metric values are presented in Table 3. Habitat was evaluated at seven transects in Stetson's Slip,five in Arnold's Slip, and three in Mason's Slip. Mason's slip. Mason's Slip was the deepest and widest, and Stetson's Slip was the longest. The highest percent overhanging vegetation was in Arnold's Slip. Silt was the dominant substrate in the SBCRS. The majority of the fine sediments in the SBCRS were in the east-west middle of each slip. Arnold's Slip had the highest amount of fine sediments, with a maximum depth of fines of 2.5 meters (at the beginning transect). The maximum measurement of depth of fines in Arnold's Slip was more than twice the maximum depth of fines in Stetson's and Mason's Slips. Mason's Slip's shoreline had the most riprap and constructed vertical walls, with 18 percent of the shoreline stabilized with riprap and 67 percent of the shoreline had constructed vertical walls. Concrete and vertical walls were prevalent throughout all three slips. Manmade structures were present in all three SBCRS. Stetson's Slip had the most with a total of five structures. No macrophytes or spawning areas were observed in the slips.

Sediment Chemistry

Sediment quality can considerably impact overlying water quality, benthic community structure, food chain dynamics, and other elements of freshwater ecosystems. Since sediment can act as a reservoir for persistent or bioaccumulative contaminants, sediment data can reflect a long-term record of quality. Some of the sources of pollutants that contaminate river sediments include direct input from industrial and municipal waste dischargers, polluted runoff from urban and agricultural areas, and atmospheric deposition (USEPA, 2001). It should be noted that sediment data from grab samples can be difficult to interpret, as samples may reflect a "hot spot," or an area with an unusually high concentration of a specific pollutant. This can be caused by an accidental release or spill of contaminants that migrate through the water column and resides in the sediment. Sufficient data were not available to do a thorough data evaluation including statistical analysis because sediment was sampled only once during this study.

Sediment Quality Guidelines. Sediment Quality Guidelines (SQGs) have been derived for some common chemicals of concern (COC) as a tool to assess contaminated sediments (Mac Donald et al., 2000a and Persaud et al., 1993). The COC in this report are ten PAHs, arsenic, and eight trace metals. Two effect level concentrations were identified for each substance: a threshold effect concentration (TEC) and a probable effect concentration (PEC). Concentrations below the TEC indicate no potential for adverse effects on sediment-dwelling organisms. Concentrations above the PEC indicate that adverse effects on sediment-dwelling organisms are likely.

General Chemistry and Trace Metals. The concentrations of the constituents measured in sediment from the center of the waterway at the beginning, middle, and end transects in the SBCRS are presented in Table 4.

TABLE 3: SUMMARY OF HABITAT METRICS IN SOUTH BRANCH CHICAGO RIVER SLIPS DURING 2013

Metric	Mason's Slip	Stetson's Slip	Arnold's Slip
Number of Transects	3	7	5
Mean Depth (m)	3.5	2.0	1.5
Mean Width (m)	49	31	28
Total Length (m)	240	630	415
Total Shoreline Length (m)	515	1,280	850
Maximum Depth of Fines (m)	1.1	1.0	2.5
Predominant Sediment Component	Silt	Silt	Silt
Predominant Bank Type	Concrete and sheet piling constructed vertical walls	Concrete armored	Mostly natural with some concrete
Maximum Depth (m)	6.1	4.0	3.0
Percent Constructed Vertical Walls	67	14	39
Percent Riprap Banks	18	2	0
Number of Manmade Structures	3	5	3
Percent Overhanging Vegetation	<5	10	15

TABLE 4: CONCENTRATIONS OF CONSTITUENTS IN SEDIMENT COLLECTED FROM SOUTH BRANCH CHICAGO RIVER SLIPS ON MAY 15, 2014, COMPARED TO APPLICABLE THRESHOLD AND PROBABLE EFFECT CONCENTRATIONS

Constituent	TEC[1]	PEC[2]	Mason's Slip			Stetson's Slip			Arnold's Slip		
			Beginning	Middle	End	Beginning	Middle	End	Beginning	Middle	End
	%										
Total Solids	NA	NA	28.7	30.8	28.3	23.9	26.6	26.1	10.9	24.0	21.2
Volatile Total Solids	NA	NA	14	28	15	15	14	13	22	15	18
	mg/kg, dry weight										
Ammonia Nitrogen	NA	NA	184	87	138	347	118	116	981	224	158
Nitrite + Nitrate Nitrogen	NA	NA	20.18	22.09	20.51	24.66	18.95	18.54	51.54	25.93	25.92
Total Kjeldahl Nitrogen	NA	NA	4,624	4,347	3,784	5,276	4,056	4,118	12, 219	5,077	6,308
Total Phosphorus	NA	NA	3,924	3,108	3,367	4,387	3,635	3,025	8,117	5,649	6,341
Phenol	NA	NA	0.476	0.430	0.467	0.485	0.549	0.449	1.850	0.604	2.161
Cyanide	NA	NA	1.522	0.836	0.805	1.504	0.575	0.672	5.009	1.076	0.801
Arsenic[3]	9.8	33	<5	<5	<5	5	<5	<5	9	5	5
Cadmium[3]	0.99	5.0	10	8	9	7	7	5	5	9	7
Chromium[3]	43	110	116	90	107	88	96	75	70	109	93
Copper[3]	32	150	280	216	258	242	247	219	241	280	311
Iron[4]	20,000	40,000	22,907	20,290	24,205	21,005	26,292	24,314	17,435	25,858	25,465
Lead[3]	36	130	215	234	264	205	195	176	198	252	273
Manganese[4]	NA	NA	349	294	384	318	382	391	263	368	358
Mercury[3]	0.18	1.1	0.845	0.605	0.783	0.776	0.686	0.660	0.738	0.857	0.762
Nickel[3]	23	49	34	30	33	32	33	32	29	35	36
Silver	NA	NA	6	5	6	5	5	4	4	5	5
Zinc[3]	120	460	709	532	635	659	692	609	647	877	1,012

NA = Not available.
[1]Threshold effect concentration.
[2]Probable effect concentration.
[3]TECs and PECs are from MacDonald et al., 2000a
[4]TECs and PECs are from Persaud et al., 1993

Table 4 also shows TECs and PECs available for eight trace metals and arsenic found in sediments from the SBCRS. Overall, 49 percent of the sediment samples taken from the SBCRS had concentrations of trace metals above established PECs. Arnold's Slip had the highest concentrations of most of the chemical parameters and trace metals. The beginning of Arnold's Slip had noticeably higher amounts of the nitrogen species and total phosphorus, phenol (beginning and end sample points), cyanide and arsenic. Even though the beginning of Arnold's Slip had the highest concentration of arsenic in the SBCRS, the concentration was not above the TEC. The end sampling location in Arnold's Slip had the highest concentrations of copper, lead, and zinc, but all of the sampling locations within the SBCRS had concentrations above their respective PECs. Concentrations of mercury, and nickel were above the TEC for all sampling locations in the SBCRS. Concentrations of cadmium were above the PEC for all sampling locations, except the end of Stetson's Slip and the Beginning of Arnold's Slip in the SBCRS.

Organic Priority Pollutants. A total of 111 OPPs were analyzed in sediment samples collected from SBCRS, on May 15, 2014. Fifteen OPPs were detected in at least one of the sediment samples. The concentrations of these OPPs and available PECs are presented in Table 5. Values for TECs are not presented, because in almost all cases the reporting limits were higher than the TECs and if the reporting limits were lower than the TECs the concentrations were all much higher than the TECs. Overall, 68 percent of the sediment samples taken from the SBCRS had concentrations that were above established PECs for PAHs. Similar to the results of the chemical and trace metals concentrations, sediment in Arnold's Slip had the highest concentration of OPPs. Concentrations in all the sediment samples were below the PEC for benzo(ghi)perylene, benzo(k)fluoranthene, and indeno(1,2,3-cd)pyrene and above the PEC for benzo(a)anthracene, benzo(a)pyrene, chrysene, fluorathene, phenanthrene, and pyrene. The beginning of Mason's Slip had some of the highest concentrations of PAHs and the highest volatile solids, which could be because of the amount of barge traffic it has received and possibly from some of the coal particles that were spilled or settled out from dust during transfer from barges to the plant.

Benthic Invertebrates

The HD assemblies were in the waterways for an average of 6.4 weeks. Macroinvertebrate samples were sorted but not identified, therefore the benthic invertebrate community in the SBCRS could not be assessed. Funding was not available for a taxonomic identification contract, but samples that were collected and sorted could still be identified at a later date.

However, during a wet weather cross-sectional sampling event (September 20, 2013) live freshwater mussels were found in three different areas within Stetson's Slip. A total of 10 live (including two juveniles) *Pyganodon grandis* (giant floater) were found out of the water or in shallow water near the shoreline. Photographs were taken of the live mussels for confirmation and specimen were released back into Stetson's Slip.

Fish

Between 2013 and 2015, 15.5 hours of electrofishing yielded 7,197 fish, with a total catch weight of 600.5 kilograms (data not shown), in the SBCRS. A total of 34 fish species, including

TABLE 5: CONCENTRATIONS OF ORGANIC PRIORITY POLLUTANTS DETECTED IN SEDIMENT COLLECTED FROM SOUTH BRANCH CHICAGO RIVER SLIPS ON MAY 15, 2014, COMPARED TO APPLICABLE PROBABLE EFFECT CONCENTRATIONS

Compound	Reporting Limit	PEC[1]	Mason's Slip Beginning	Mason's Slip Middle	Mason's Slip End	Stetson's Slip Beginning	Stetson's Slip Middle	Stetson's Slip End	Arnold's Slip Beginning	Arnold's Slip Middle	Arnold's Slip End
	μg/kg dry weight										
Toluene	10	NA	ND	ND	ND	ND	ND	ND	39,500	ND	ND
Phenol	400	NA	ND	ND	ND	ND	ND	ND	ND	ND	2,080
Anthracene	300	845[a]	1,890	1,370	1,660	1,260	ND	1,340	1,500	1,380	1,640
Benzo(a)anthracene	300	1,050[a]	5,420	4,060	4,760	4,940	3,300	5,800	5,740	5,510	4,880
Benzo(a)pyrene	300	1,450[a]	2,320	1,820	1,980	2,130	1,280	2,050	1,890	2,290	2,610
3,4-Benzofluoranthene	300	NA	3,090	2,500	2,510	2,790	1,870	3,000	2,560	2,900	3,360
Benzo(ghi)perylene	300	3,200[b]	1,110	ND	799	ND	ND	1,040	ND	ND	ND
Benzo(k)fluoranthene	300	13,400[b]	3,310	2,490	2,950	3,270	1,830	3,660	3,550	3,280	3,780
Bis(2-ethylhexyl)phthalate	2,500	NA	24,000	19,600	16,600	26,300	18,300	20,500	41,300	23,700	15,000
Butylbenzyl phthalate	400	NA	ND	ND	ND	ND	ND	3,570	ND	ND	ND
Chrysene	200	1,290[a]	8,110	6,470	7,040	7,720	5,020	8,270	8,960	7,850	6,730
Fluoranthene	200	2,230[a]	12,100	8,640	10,100	10,500	6,280	10,400	11,300	9,360	11,300
Indeno(1,2,3-cd)pyrene	300	3,200[a]	1,040	ND	753	ND	ND	ND	ND	ND	ND
Phenanthrene	200	1,170[a]	8,020	5,000	6,980	5,810	3,090	5,500	7,410	5,650	6,810
Pyrene	200	1,520[a]	11,500	7,290	8,440	8,330	5,130	8,240	6,630	7,940	9,640

NA = Not available.
ND = Not detectable.
[1]Probable effect concentrations.
[a]Probable effect concentrations from MacDonald et al., 2000.
[b]Probable effect concentrations from Persaud et al., 1993.

14 game species, one state threatened species, and three hybrid species were collected from the SBCRS. More than half of the fish collected were collected in Stetson's Slip.

Species Richness and Abundance. Fish species richness was highest in Stetson's Slip, but the highest number of game species was collected in Mason's Slip (Table 6). However, higher proportions of game fish species were collected in Arnold's Slip and Stetson's Slip than in Mason's Slip. Gizzard shad was the most abundant fish species in the SBCRS and accounted for over 40 percent of the overall collection in Stetson's and Mason's Slips. Species composition in relation to biomass was calculated, and common carp (*Cyprinus carpio*) was the dominant species throughout the SBCRS.

Index of Biotic Integrity. All of the individual IBI scores for the each of the fish sampling events in the SBCRS were in the Fair category (21–40) and the highest individual IBI score for the SBCRS was 38 (Mason's Slip) (data not shown). The mean IBI scores for the slips were very similar (Table 7). Lack of sucker, darter, intolerant, and insectivore species were some of the metrics that limited IBI scores to the Fair category.

Fish Abundance. There were no statistically significant differences between SBCRS CPUE means for total catch, as determined by one-way ANOVA ($p = 0.87$) (Table 8). Since there were no significant differences between CPUE means of the total amount of fish collected in each of the SBCRS, we tested for statistical significance via ANOVA for CPUE of game fish to see if game fish preferred one slip over another, and no statistical significance was found ($p = 0.61$). We then tested for statistical significance of CPUE of largemouth bass alone, because the abundance of largemouth bass in Stetson's Slip was what initially drew our attention to the slips while assisting with another study, and no statistical significance was found for largemouth bass CPUE means ($p = 0.85$). Since no statistical significance was found, we did not conduct any post hoc tests for CPUE data.

Dissolved Oxygen Cross-Sectional Profiling

Seasonal DO cross section events were attempted nine times and wet weather DO cross section event were attempted six times, but only seven of the seasonal and five wet weather events were completed. Incomplete events were a result of technical difficulties and data from these events were not used for statistical analysis. Overall, no low DO concentrations (<2 mg/L) were observed during DO cross section events during dry seasonal weather or during electrofishing events. However, during wet weather DO cross sections events, 4.4 percent of the measured DO concentrations were below 2 mg/L with over half of those measurements recorded in Arnold's Slip.

Overall, DO concentrations were higher during seasonal dry conditions than wet weather conditions for all transects. Statistical significance of mean DO concentrations was found between and within SBCRS and main channel locations during dry and wet weather (Tables 9 and 10). Table 9 shows that mean DO concentrations of Arnold's Slip and Stetson's Slip were significantly lower than Loomis Street, during seasonal dry conditions, when comparing the mean DO concentrations of the entire slips and main channel locations. During wet weather, only the mean

TABLE 6: NUMBER AND PERCENT COMPOSITION OF FISH SPECIES COLLECTED IN SOUTH BRANCH CHICAGO RIVER SLIPS BETWEEN 2013 AND 2015

Fish Species or Hybrid (x)	Arnold's Slip		Stetson's Slip		Mason's Slip	
	Number[1]	%	Number	%	Number	%
Alewife	0	0.00	2	0.05	2	0.15
Banded killifish	6	0.31	14	0.35	12	0.91
Black bullhead[2]	1	0.05	0	0.00	0	0.00
Black crappie[2]	2	0.10	1	0.03	1	0.08
Blackstripe topminnow	0	0.00	2	0.05	1	0.08
Bluegill[2]	358	18.60	642	16.24	206	15.61
Bluntnose minnow	229	11.90	278	7.03	157	11.89
Brook silverside	2	0.10	1	0.03	0	0.00
Channel catfish[2]	17	0.88	29	0.73	3	0.23
Chinook salmon[2]	0	0.00	0	0.00	1	0.08
Common carp	56	2.91	67	1.70	25	1.89
Emerald shiner	1	0.05	1	0.03	1	0.08
Fathead minnow	17	0.88	5	0.13	1	0.08
Freshwater drum	0	0.00	1	0.03	0	0.00
Gizzard shad	452	23.48	1,654	41.85	561	42.50
Golden shiner	238	12.36	146	3.69	28	2.12
Goldfish	1	0.05	3	0.08	2	0.15
Green sunfish x Bluegill	1	0.05	11	0.28	0	0.00
Green sunfish[2]	115	5.97	374	9.46	135	10.23
Green sunfish x Pumpkinseed	1	0.05	9	0.23	0	0.00
Johnny darter	0	0.00	1	0.03	0	0.00
Largemouth bass[2]	118	6.13	282	7.14	82	6.21
Western mosquitofish	1	0.05	0	0.00	1	0.08
Northern pike[2]	0	0.00	0	0.00	1	0.08
Orangespotted sunfish[2]	9	0.47	5	0.13	0	0.00
Oriental weatherfish	2	0.10	0	0.00	1	0.08
Pumpkinseed[2]	214	11.12	366	9.26	38	2.88
Pumpkinseed x Bluegill	4	0.21	6	0.15	0	0.00
Round goby	6	0.31	10	0.25	2	0.15
Sand shiner	0	0.00	1	0.03	0	0.00
Spotfin shiner	62	3.22	10	0.25	44	3.33
Spottail shiner	1	0.05	0	0.00	0	0.00
Warmouth[2]	0	0.00	4	0.10	1	0.08
White sucker	0	0.00	1	0.03	0	0.00
Yellow bass[2]	0	0.00	2	0.05	0	0.00
Yellow bullhead[2]	11	0.57	24	0.61	13	0.98
Yellow perch[2]	0	0.00	0	0.00	1	0.08

TABLE 6 (Continued): NUMBER AND PERCENT COMPOSITION OF FISH SPECIES COLLECTED IN SOUTH BRANCH CHICAGO RIVER SLIPS BETWEEN 2013 AND 2015

Fish Species or Hybrid (x)	Arnold's Slip		Stetson's Slip		Mason's Slip	
	Number[1]	%	Number	%	Number	%
Total number of fish	1,925		3,952		1,320	
Total Species	26		30		25	
Total Game Species	9		10		11	
Total Hybrid Species	3		3		0	

[1]Number of fish collected.
[2]Game species.

TABLE 7: SUMMARY OF FISH INDEX OF BIOTIC INTEGRITY METRICS FOR SOUTH BRANCH CHICAGO RIVER SLIPS BETWEEN 2013 AND 2015

Mean of Fish IBI[1] Metrics	Arnold's Slip	Stetson's Slip	Mason's Slip
Number of Fish Species	11.5	12.9	10.6
Number of Sucker Species	0.0	0.1	0.0
Number of Sunfish Species	3.3	3.8	3.1
Number of Darter Species	0.0	0.1	0.0
Number of Intolerant Species	0.8	1.0	0.9
Proportion of Green Sunfish	6.2	11.1	10.0
Proportion of Hybrids	0.4	0.9	0.0
Proportion of Disease	1.1	1.1	1.7
Proportion of Omnivores	51.4	49.8	51.5
Proportion of Insectivores	2.6	0.3	3.0
Proportion of Carnivores	7.0	9.0	8.2
Total Abundance	241	494	165
IBI Score	33	31	32

[1]Index of Biotic Integrity.

TABLE 8: SUMMARY OF CATCH PER UNIT EFFORT DATA OF FISH COLLECTED IN SOUTH BRANCH CHICAGO RIVER SLIPS BETWEEN 2013 AND 2015

SBCR[2] Slip	Count	Total Fish CPUE[1]				Game Fish CPUE				Largemouth Bass CPUE			
		Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.
		Fish/hr											
Arnold's Slip	8	198	572	436	139	9	297	180	115	2	80	27	25
Stetson's Slip	8	168	719	482	195	123	397	213	91	6	120	34	35
Mason's Slip	8	244	960	438	239	95	305	167	71	3	66	28	25
p Value[3]				0.87				0.61				0.85	
F-Statistic[3]				0.14				0.51				0.17	

[1]Catch per unit effort (fish/hour).
[2]South Branch Chicago River.
[3]One-way Analysis of Variance statistical analysis with two degrees of freedom between groups and 21 within groups for all three tests.

TABLE 9: MEAN DISSOLVED OXYGEN CONCENTRATIONS IN SOUTH BRANCH CHICAGO RIVER SLIPS AND MAIN CHANNEL SAMPLING LOCATIONS DURING DRY AND WET WEATHER CONDITIONS, BETWEEN 2013 AND 2015

Sampling Event Type	Slip or Station Name	N	Mean	Std. Dev.	Significance Probability H_0: Equal μ	Rank[1]
Dry[2]	Loomis Street	84	6.235	0.805	0.000	A
Dry	Mason's Slip	226	6.140	0.725		AB
Dry	Ashland Avenue	80	6.020	0.765		AB
Dry	Arnold's Slip	164	5.836	1.255		B
Dry	Stetson's Slip	203	5.397	1.033		C
Wet[3]	Mason's Slip	162	4.344	1.162	0.005	A
Wet	Loomis Street	60	4.295	1.378		AB
Wet	Stetson's Slip	143	4.068	1.201		AB
Wet	Ashland Avenue	59	3.989	1.525		AB
Wet	Arnold's Slip	123	3.767	1.526		B

[1]Within each Sampling Event Type, means followed by the same letter are not significantly different at the 0.05 probability level.
[2]Sampled during the spring, summer or fall during dry conditions.
[3]Sampled within 24 hours of Racine Avenue Pumping Station activity.

TABLE 10: MEAN DISSOLVED OXYGEN CONCENTRATIONS IN TRANSECTS WITHIN SOUTH BRANCH CHICAGO RIVER SLIPS AND MAIN CHANNEL SAMPLING LOCATIONS DURING DRY AND WET WEATHER CONDITIONS BETWEEN 2013 AND 2015

Transect	Sampling Event Type	Slip or Station Name	N	Mean	STD	Significance Probability H_0: Equal μ	Rank[1]
Beginning (South)	Dry[2]	Loomis Street	84	6.235	0.805	0.028	A
		Mason's Slip	83	6.108	0.745		AB
		Stetson's Slip	62	6.096	0.766		AB
		Ashland Avenue	80	6.020	0.765		AB
		Arnold's Slip	59	5.797	0.933		B
	Wet[3]	Mason's Slip	59	4.374	1.256	0.512	A
		Stetson's Slip	44	4.341	1.453		A
		Loomis Street	60	4.295	1.378		A
		Arnold's Slip	44	4.046	1.622		A
		Ashland Avenue	59	3.989	1.525		A
Middle	Dry	Loomis Street	84	6.235	0.805	0.000	A
		Mason's Slip	81	6.095	0.689		A
		Ashland Avenue	80	6.020	0.765		A
		Arnold's Slip	54	5.872	0.733		A
		Stetson's Slip	70	5.048	0.923		B
	Wet	Mason's Slip	58	4.367	1.095	0.000	A
		Loomis Street	60	4.295	1.378		AB
		Ashland Avenue	59	3.989	1.525		ABC
		Arnold's Slip	40	3.568	1.194		BC
		Stetson's Slip	49	3.529	0.603		C
End (North)	Dry	Mason's Slip	62	6.241	0.745	0.000	A
		Loomis Street	84	6.235	0.805		A
		Ashland Avenue	80	6.020	0.765		A
		Arnold's Slip	51	5.844	1.884		A
		Stetson's Slip	71	5.129	1.051		B
	Wet	Stetson's Slip	50	4.355	1.237	0.111	A
		Loomis Street	60	4.295	1.378		A
		Mason's Slip	45	4.275	1.139		A
		Ashland Avenue	59	3.989	1.525		A
		Arnold's Slip	39	3.657	1.701		A

[1]Within each sampling event type, means followed by the same letter are not significantly different at the 0.05 probability level.
[2]Sampled during the spring, summer or fall during dry conditions.
[3]Sampled within 24 hours of Racine Avenue Pumping Station activity.

DO concentration of Mason's Slip was significantly higher than Arnold's Slip. Table 10 shows no statistical difference between the mean DO concentrations during wet weather in the beginning and end transects and the main channel transects. Also during wet weather, mean DO concentrations in middle transect of Mason's Slip were significantly higher than middle transect DO concentrations in Stetson's and Arnold's Slips. During seasonal dry conditions, mean DO concentrations were significantly higher at Loomis Street than the beginning transect in Arnold's Slip. The mean DO concentrations at the middle and end transects in Stetson's Slip were significantly lower than all other transects, during dry seasonal conditions. During wet weather conditions, mean DO concentrations were significantly higher in the middle transect in Mason's Slip than in Arnold's and Stetson's Slips. Also, no statistical significance was found between mean DO concentrations of the right, left or center positions of transects within the SBCRS. During wet weather, the mean DO concentration of the middle transects was significantly lower than the mean DO concentrations of the end and beginning transects in Stetson's Slip ($p = 0.000$). During seasonal dry weather the mean DO concentration of the beginning transects was significantly higher than the mean DO concentrations of the middle and end transects ($p = 0.000$).

DISCUSSION

Habitat in the SBCRS is somewhat similar to the habitat in the main channel of the SBCR with subtle differences. When LimnoTech evaluated the habitat in various reaches of the CAWS, the SBCR and the CSSC equally had the lowest CAWSHI score (LimnoTech, 2010). The CAWS and SBCRS lack sinuosity, flow, and sizeable littoral zones, rooted aquatic vegetation and have a high percentage of vertical banks. All of the SBCRS had habitat features that LimnoTech determined to be negatively associated with fish data, and only Stetson's Slip and Arnold's Slip had noteworthy amounts of overhanging vegetation which was the only feature, according to LimnoTech (2010), that was positively associated with fish data measured in this study (Table 4).

The SBCRS have some positively correlated habitat features that are essentially absent in the surrounding areas like the SBCR and Bubbly Creek. The SBCRS serve as refuge areas for biota in the SBCR, in a system where refuge areas are fairly sparse or non-existent. The SBCRS provide protection from commercial and recreational boat traffic because they are perpendicular to the main channel. Stetson's and Arnold's Slips provide the most refuge because they are larger and have less boat or barge traffic. Stetson's and Arnold's slips also have some overhanging vegetation which is almost non-existent in main channel of the SBCR.

The wide section of Mason's Slip has relatively frequent barge traffic, because of the concrete facility on the east bank. Barge containers are routinely parked on the east side of the slip and unloaded. In the recent past, a coal fired power plant was operational on the west bank of Mason's Slip, generating electrical power and heavy barge traffic. However, the northernmost section of Mason's Slip is relatively shallow when compared to the rest of the slip. The maximum depth in the SBCRS is also less than the main channel of the SBCR, especially in Stetson's and Arnold's slips (four and three meters, respectively) (Table 4). LimnoTech determined that the maximum depth in the SBCR was approximately seven meters (LimnoTech, 2010). Large maximum depths can provide good habitat for fish, because fish require deeper water for overwintering, but in the SBCR (and the CAWS) there is an abundance of deep open water, lack of developed littoral zones, and little to no off-channel areas that limit aquatic life uses (LimnoTech, 2010). Most species of fish and other aquatic life require shallow areas during important life stages.

LimnoTech determined that manmade structures negatively correlated to fish data in the CAWS, but there may be some exceptions. Three out of the five manmade structures in Stetson's Slip were sunken structures (i.e. two boats and a platform). Sunken boats, bridge abutments and sheet piling clad and wooden dolphins were considered manmade structures in this study. During electrofishing fish were not noticeably more abundant in or near sunken structures in Stetson's Slip. It is unlikely they have negative impacts on fish abundance, considering boats are sunken on purpose to create artificial reefs in marine systems. Even the railroad tie structure (which was counted as a manmade structure) that is near the back end of Stetson's Slip could provide added refuge to biota, when water levels are at normal or higher levels (Figure 3).

A positive impact of manmade bank stabilizing structures was also observed in Stetson's and Arnolds slips. It appeared that there was an attempt to stabilize portions of the banks (primarily a segment of the east bank in Arnold's Slip and large portions of the east and west banks in

FIGURE 3: HIDDEN HABITAT FEATURES FOUND IN STETSON'S SLIP DURING LOW WATER CONDITIONS

Railroad tie structure

Undercut bank pocket

Undercut bank

Stetson's Slip) by pouring concrete toward the edge of the water's edge. Over time, topsoil has been added and water eroded pockets of bank material underneath the concrete and has created individual pockets and areas with undercut banks, that are potential refuge and are visible when water levels are extremely low (Figure 3). During this study, such habitat features were only observed once while doing wet weather DO cross sectional profiling on September 20, 2013.

Arnold's Slip and Mason's Slip provide a smaller amount of off-channel habitat than Stetson's Slip. Improving habitat in the SBCRS would provide even more refuge for aquatic biota in the SBCR. The addition of more littoral zones in the SBCRS would aid in the establishment of aquatic macrophytes. Weber et al. (2012) were able to significantly increase the diversity and density of aquatic vegetation over time in constructed artificial shallows. Fish and other biota rely on aquatic vegetation and littoral zones for reproduction, nursery areas, food, and protection from larger predators. The addition of more bank pocket areas and undercut banks would provide more areas of refuge for aquatic biota. Bank pocket areas and undercut banks were not specifically measured in this study, but it appeared that Stetson's Slip had more of these types of habitat from general field observations. Arnold's Slip and Mason's Slip are smaller than Stetson's Slip and also have higher percentages of constructed vertical walls, thus limiting the number of areas where undercut bank pocket areas can exist. Submerged undercut banks have been shown to provide higher densities of macroinvertebrate than riffles or pools at times, in low gradient streams (Rhodes and Hubert, 2004). Higher densities of macroinvertebrates provide more food for fish and would likely increase the ability of the SBCRS to provide more refuge areas for aquatic biota. Mason's Slip would benefit from some protection from barge traffic, because the front half of that slip is still used by barges. An artificial peninsula made of wave breaking materials that still allows some water through and possibly creating more shallow areas could be constructed either around the barge docking area for the concrete facility or across most of the slip north of where the docking area ends. All of the biota in the SBCRS could benefit from some additional instream habitat, and the SBCRS (especially Stetson's Slip and Arnold's Slip) are potentially a good area to add instream habitat because navigation is not a concern in some of or parts the SBCRS. Main channel areas in the CAWS are maintained for navigation which, at times, includes removing potential instream habitat because it hinders navigation.

Arnold's Slip is located directly across the SBCR from Bubbly Creek, which is currently impaired for TP and DO (IEPA, 2016). RAPS is located at the southern end of Bubbly Creek. During periods of pumping at RAPS, combined sewer overflows (CSOs) are discharged north into the river. Fine particles settling out of the water column from CSOs and from RAPS are a possible source of the accumulation of fine sediments in Arnold's Slip, especially given the relatively higher concentrations of nitrogenous and phosphoric compounds in the sediment at the beginning of Arnold's Slip. Concentrations of these same compounds decrease throughout the rest of the slip and are comparable to those in the other SBCRS.

Low DO concentrations (<2 mg/L) can have an immediate impact on aquatic biota and long term impacts on biota if they are exposed to low DO conditions for extended periods of time. Low DO can impact aquatic biota abundance, behavior, fecundity, and other physiological processes. No low DO concentrations were observed during seasonal dry weather DO cross sections or electofishing events and only 4.4 percent of DO values recorded during wet weather events were below 2 mg/L. It appears that DO was unlikley the limiting factor impacting fish abundance, behavior and productiveness in the SBCRS.

Despite having areas of fine sediments containing concentrations of many constituents above the PECs, Stetson's Slip had large enough areas with suitable habitat to support a population of giant floaters in three separate locations within the slip. The observed population included adults and juveniles, suggesting that population may be stable. The presence of a stable population of giant floaters in Stetson's Slip was unusual in the CAWS, because collection of Unionid mussels during the routine biological monitoring by District personnel is rare. However, when considering the natural history of giant floater species of mussel, it is not surprising to find giant floaters in Stetson's Slip. Giant floaters native to Illinois and are typically found in ponds, lakes, or sluggish muddy substrates and thrive in impoundments (Cummings and Cordeiro, 2012). Giant floaters are also sedimentation and pollution-tolerant (Cummings and Cordeiro, 2012), which makes the SBCRS an ideal habitat for this species.

The fish communities in the SBCRS were very similar throughout each of the three slips. Overall, Stetson's Slip yielded the highest cumulative number of species throughout the duration of this study (Table 7). However, mean fish taxa richness, IBI scores, and various other IBI metrics were very similar between the SBCRS (Table 8). Given the maximum IBI score obtained in the SBCRS during the study was 38, it is possible that an IBI score in the Good range (41-60) could be occasionally achieved with the current habitat in the SBCRS. With the addition of quality habitat features or improvement of existing habitat, IBI scores could potentially be in the Good range on a regular basis.

It should be noted that the proportion of hybrids (sunfish hybrids) were higher in Stetson's Slip and Arnold's Slip, suggesting that spawning habitat nearby or in the slips is somewhat limited. Sunfish have a known propensity to hybridize in certain conditions, including having a limited amount of spawning sites causing nests to be exchanged between species (Avise and Saunders, 1984). No spawning areas were observed during this study, but that doesn't mean that they are absent within the SBCRS. It is more likely that the number of spawning sites are limited and not visible during the study.

There was no significant difference between mean CPUE of total number of fish, game fish, or largemouth bass (Table 8). Although not significantly different in means likely due to large variation in the results from individual sampling, it should be noted that Stetson's Slip had the highest magnitude of mean CPUE for total number of fish, game fish, and largemouth bass. There could be a number of reasons why this was the case, but it is likely that the hidden habitat features (Figure 3) may have played a role. CPUE was variable from one sampling event to the other, which is very common in electrofishing due to the varying efficiency that is determined by weather and water conditions.

The differences in mean DO concentrations appeared to be due to influence of season, location, and CSO discharge during pumping at RAPS. Mean DO concentrations in Stetson's Slip (the slip with the highest CPUE and number of species of fish) were significantly lower than all the other slips and main channel locations during seasonal dry conditions (Table 9). During wet weather, mean DO concentrations were significantly lower in Arnold's Slip than Mason's Slip (Table 9), which could be due to the influence of RAPS, because wet weather events were defined periods during or within 24 hours of pumping at RAPS. It was likely that Mason's Slip and Stetson's Slip were not heavily influenced by CSO from RAPS, because they are located upstream of the confluence with Bubbly Creek, especially Mason's Slip which is located approximately

1,135 meters upstream (Figure 1). Mean DO concentrations in the middle and end transects of Stetson's Slip were significantly lower than the other the other middle, end, and main channel transects during seasonal dry conditions (Table 10), possibly because Stetson's Slip is the longest of the SBCRS and therefore has the longest stretch of stagnant water. SOD might also deplete DO more in that long stretch of stagnant water than in the other SBCRS. However, during wet weather conditions mean DO concentrations were actually the highest in the end transect of Stetson's Slip when compared to the other SBCRS end transects or main channel transects. Overall, mean DO concentrations were higher at all locations during dry weather. The end transect in Stetson had the lowest mean DO concentration during dry weather when compared to the other end transects and main channel location, but had the highest mean DO concentration during wet weather. Because mean DO concentrations at the end transect of Stetson's Slip changed the least between wet and dry weather, compared to the other end transects and main channel locations, it is likely that the end transect in Stetson's Slip is the least influenced by wet weather.

Fish data collected during this study suggests that DO concentrations in the range detected (3.6 to 7.9 mg/L) might have little impact on which slip fish prefer to stay. Stetson's Slip had the highest mean CPUE and number of fish species, but the lowest mean DO concentration during dry weather. Gaulke et al. (2015) found that largemouth bass did not move much in Stetson's Slip to avoid low DO (<2 mg/L) areas. They preferred to stay in areas with preferred habitat even when DO concentrations were less than 2 mg/L. It is also likely that some the fish in the SBCRS had home ranges that included at least Arnold's Slip and Stetson's Slip and maybe all three of the SBCRS, and with respect to fish habitat, the SBCRS could be viewed to function as a unit and not just individual off-channel areas.

Future Studies

Currently, the SBCR is impaired for low DO, total dissolved solids, and fish consumption (due to polychlorinated biphenyls [PCBs]) (IEPA, 2016), but water quality in the CAWS has improved since the Clean Water Act, due to improvements in wastewater treatment and the Tunnel and Reservoir Plan (TARP). The District is currently working on a number of major projects to further enhance water quality of the CAWS, including nutrient removal and the activation of the McCook Reservoir. As water quality improves, the CAWS could be potentially more inviting to intolerant species, but the presence and behavior of fish is not solely dependent on water quality (LimnoTech, 2010 and Gaulke et al., 2015). Fish and other aquatic biota have preferred habitats, and if that habitat is not present in a waterway, resident populations will not establish even if the water quality is optimal.

The SBCRS provide some unique areas of refuge, but it is likely that they could provide even more refuge to biota with the installation of additional habitat features or the modification of existing features. This study did not fully assess the impact of the elevated concentrations of metals and PAHs on the bottom-dwelling biota. Further assessment could be necessary to determine if sediment remediation could help to improve aquatic life use in the SBCRS. Evaluation of other off-channel habitat areas in the CAWS could be an opportunity to improve aquatic habitat with minimal economic resources. Adding more artificial habitat or improving existing habitat within off-channel areas could be a good investment, because many of these areas are not used by barges and do not need to be clear of obstacles to navigation.

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