Changing Habitat and Biodiversity of the Lower Milwaukee River and Estuary

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COVER PHOTO: Capitol Drive station (previously impounded), Milwaukee River, 1998, WDNR

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Summary

The 150-year old North Avenue Dam built on the Milwaukee River 5.1 kilometers (km) upstream from the confluence with Lake Michigan was removed in 1997. The dam, when it existed, created an impoundment approximately 3.7 km long and 33 hectares. Following many decades of impounding, sediment deposition, discharges from rural and urban stormwater, poorly treated wastewater discharges throughout the watershed and local combined sewer overflows into the river, the water quality and habitat was severely degraded. Low dissolved oxygen levels resulting from sediment oxygen demand and respiration by aquatic plants, deposition by over 22,000 m^3 of fine textured and contaminated sediment contributed to a fish community reduced to only a few tolerant species. With the removal of the dam, sewage treatment improvements and combined sewer overflow abatement, riverine conditions began to reestablish in the formerly impounded area fairly quickly. The removal of the dam not only provided an opportunity for migratory fish species to move further upstream, it also opened up opportunities for rehabilitation of some of the native species that were extirpated, or reduced to remnant populations.

As part of the initial biological investigation, the Wisconsin DNR developed a sampling protocol to survey and document changes in fish assemblages in the formerly impounded area. In addition, we also selected several other sites upstream of the impoundment that were not impacted by the dam. Some sites were located downstream of the former dam and in the harbor. This is the first detailed survey conducted since the dam was removed. Our objective was to describe the fish community, assess overall biological integrity, and evaluate fish community changes over a period of six years (1996-2001). We selected two long-term index sampling sites - one formerly impounded site (Capitol Drive station), and the other an upstream site (Kletzsch Park station). Because of its abundance, water quality requirements and local importance, we chose smallmouth bass as an intensive study species to delineate its population characteristics. Fish samples were collected using a stream shocker, a mini-boomshocker or a boomshocker depending on the depth and flow conditions at the station. A consistent sampling protocol was used following WDNR sampling guidelines for assessing fish communities.

Improvements in the riverine habitat following dam removal increased biological diversity several fold in the formerly impounded area. The total number of species captured in this section increased from seven species in 1996 to 37 species, overall. The number of native species has increased five-fold. The greater redhorse, a state-listed threatened species, was captured consistently. Smallmouth bass became the most abundant game species with multiple strong year-classes. The overall environmental quality measured as the Index of Biotic Integrity (IBI) in the formerly impounded area increased from 20 (Poor) in 1996 to 80 (Excellent) in 2000-2001.

WDNR, along with other contracting companies, implemented a variety of habitat improvement measures including bank stabilization, constructing bendway weirs,

instream boulder clusters and willow tree planting. With the improvement in water quality and habitat, WDNR initiated native walleye and lake sturgeon restoration projects in the Lower Milwaukee River and Estuary. Since 1995, we have attempted to stock approximately 10,000 extended growth walleye fingerlings annually. They are surviving and growing well, supporting a limited nearshore fishery. In general, the removal of the North Avenue Dam along with point source and combined sewer overflow pollution abatement has opened up many opportunities to enhance fishing in the area through improved water quality and increased river miles for both resident and migratory fish.

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Changing Habitat and Biodiversity of the Lower Milwaukee River and Estuary

1.0. Introduction

The Lower Milwaukee River and Estuary habitat and water quality have been heavily altered due to damming, channelization, streambank modification by riprap and sheet piling, and industrial discharge. The International Joint Commission (IJC) identified the Milwaukee Estuary as one of 43 Areas of Concern (AOC) requiring clean up of toxic wastes and remedial action (WDNR 1994).

The Milwaukee River Estuary AOC is located at the lower limits of the Milwaukee River Basin (2200 km^2) and includes the Milwaukee Inner and Outer Harbors, the Milwaukee River downstream of the former North Avenue Dam, the Menomonee River downstream from 26^{th} Street and the Kinnickinnic River downstream from Chase Avenue. However, the highest quality waters lie in the upstream areas that are least affected by development and agricultural impact. In general, most of the stream miles in the Milwaukee River Basin are considered to have the ability to support a full range of fish and aquatic life (WDNR 2001). Fifty eight percent of the basin stream miles are capable of supporting warm water sport fish communities, 12 percent support warm water forage fish communities, and 12 percent are capable of supporting cold water communities.

The North Avenue Dam was constructed in 1835 approximately 5.1 km (3.4 miles) upstream of the Milwaukee River confluence with Lake Michigan. The dam measured 5.2 meters high by 107 meters wide, and impounded an area of approximately 33 hectares with a pool length of about 3.7 kilometers. Water depth in the impoundment ranged from 3.6 meters to less than 0.3 meter. The dam was originally built to regulate the water level in the Milwaukee River and the proposed Rock River canal. However, the canal project was abandoned as the canal company went bankrupt and handed over the property to the City of Milwaukee. The dam provided the city no other function other than the maintenance of a pool of water for recreational purposes, and ice harvesting in the winter. The North Avenue impoundment was drained in 1990, with partial removal of the dam completed in 1997.

2.0. Objectives of the study

Removal of the North Avenue Dam allowed the Department to monitor the recovery of the fish assemblage in the previously impounded area, as well as to initiate species restoration and fish habitat improvement projects.

The main objectives of the study are:

a) To describe the fish community in the Lower Milwaukee River and Estuary post dam removal.
b) To measure the overall habitat quality upstream of the dam.

c) To evaluate long-term changes in the fish community by index sampling following dam removal.
d) To restore native fish species by initiating a stocking program.
e) To improve stream habitat quality for both resident and migratory fish species.

3.0. Methods

3.1. Study area

The study area encompassed the Milwaukee Harbor, the Milwaukee River downstream of Kletzsch Park dam (16.9 kilometers from the river mouth), the Menomonee River downstream of 26th Street, and the Kinnickinnic River downstream of Chase Avenue (Figure 1).

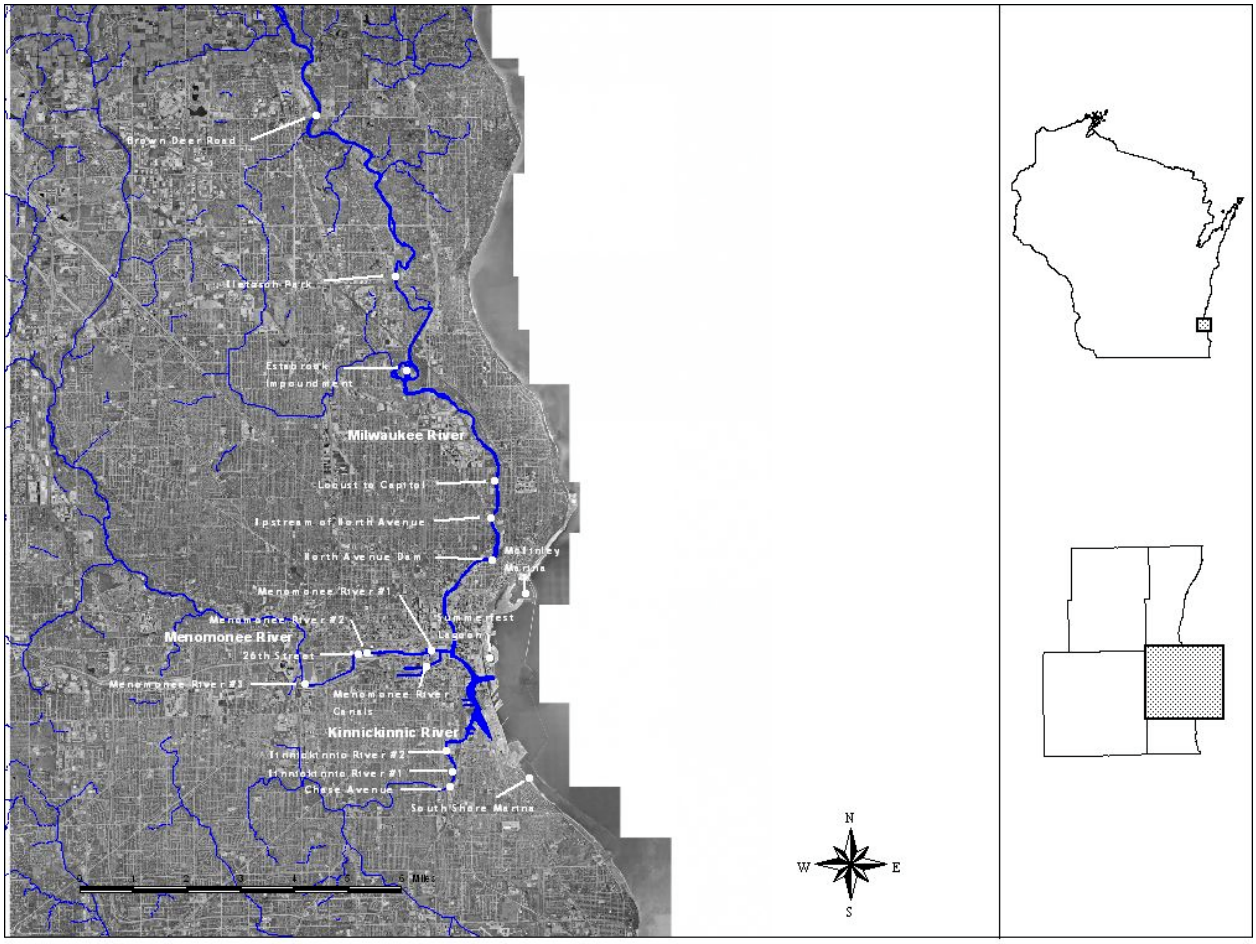

Figure 1. Distribution of sampling sites in the Lower Milwaukee River and Harbor.

The habitat in the lower reaches of the study area is typical of that found in a highly urbanized environment, with exclusive channelization and placement of sheet piling for bank stabilization. More natural habitat can be found on the Milwaukee River upstream of the former North Avenue Dam, although modified due to damming. Habitat in this

previously impounded reach has dramatically changed since drawdown and subsequent dam removal. Natural meanders have been reestablished, and scour has exposed much of the original substrate consisting of sand, gravel, cobble and rubble. Riffles and shallow runs are the dominant stream features, although deeper runs and pools are more prominent in the downstream-most reach.

Many habitat improvement measures have been implemented since the dam was removed. Streambanks have been stabilized through natural establishment of vegetation and engineered materials, including riprap, geotextiles, and open-cell articulated concrete matting (ACM) in conjunction with bioengineering techniques. Bioengineering techniques consisted mainly of live cuttings of willow placed within the open cells of the ACM and along unarmored banks for stabilization. Exposed mud flats were revegetated using a combination of native grasses and forbs. Instream habitat improvement consisted of boulder placements and the construction of a series of bendway weirs to direct current flow away from those streambanks most susceptible to erosion.

Prior to removal of the dam, the fish assemblage in the impoundment consisted mainly of pollution tolerant species. Since most records of the fish community date back to the early 1900's, it is difficult to assess the pre-dam fish community in the river. However, collections from unimpounded reaches upstream of the North Avenue impoundment from the early 1900's indicate a diverse assemblage of fish species. Fish species collected included hornyhead chub, rosyface shiner, redfin shiner, mimic shiner, silver redhorse, golden redhorse, longear sunfish, northern redbelly dace, stripped shiner, mottled sculpin and smallmouth bass (Fago, 2003). Sampling in the impounded reach through the 1970's and 1980's showed a decline in both the diversity and total numbers of fish captured. The fish community in the impoundment became dominated by common carp, white sucker, black bullhead, and green sunfish that were tolerant of the poor water quality and degraded habitat conditions present in that reach (Fago 1984). Fish kills that occurred frequently were attributed to low dissolved oxygen. An investigation conducted by WDNR to assess the fish kill that occurred in August 1990 indicated the dominance of common carp and white sucker followed by black bullhead and goldfish. The other species that were present included rock bass, green sunfish, shorthead redhorse, and fathead minnow.

3.2. Fish sampling

We followed WDNR sampling guidelines for assessing fish communities of wadable streams in Wisconsin (Simonson et al. 1994). No block nets were used. We assumed that no or minimal fish movement occurred during shocking. More detailed descriptions of the sampling procedures can be found in the methods for each sampling station.

3.2.1. Milwaukee Harbor and canals

Sampling in the Milwaukee Harbor (including McKinley Marina, Summerfest Lagoon and South Shore Marina), the Milwaukee River downstream of the former North Avenue

Dam, Menomonee River and canals, and Kinnickinnic River, was conducted using a standard WDNR pulsed-DC electroshocking boat with two dippers, following the current downstream. With few exceptions, electroshocking was conducted after sunset. For each station, we recorded the actual starting and ending time, and marked starting and ending points. Distances shocked were calculated from aerial photographs. Fish samples were collected once a year to establish relative abundance and size structure. All game species were collected into a live well on the boat. Forage species were collected in selected reaches within a station, while common carp were only observed and recorded. Biological data were collected from all game species (total length in millimeters, weight in grams), and scale samples or spines were taken from a subsample for age determination. Forage fish were identified to species and counted.

3.2.1.1. Milwaukee River downstream of the former North Avenue Dam

This station represents the river reach immediately downstream of the former North Avenue Dam. Channelization, dredging, and placement of steel sheet piling along the banks have extensively modified the habitat. The sampling stretch extended from the former dam downstream to Pleasant Street bridge (Figure 2). Water depth at this station ranged from < 1 meter to > 4 meters. The wide range of depths is due to the deposition of sediment and debris following partial failure of the articulated concrete matting in the reach between the former dam and North Avenue.

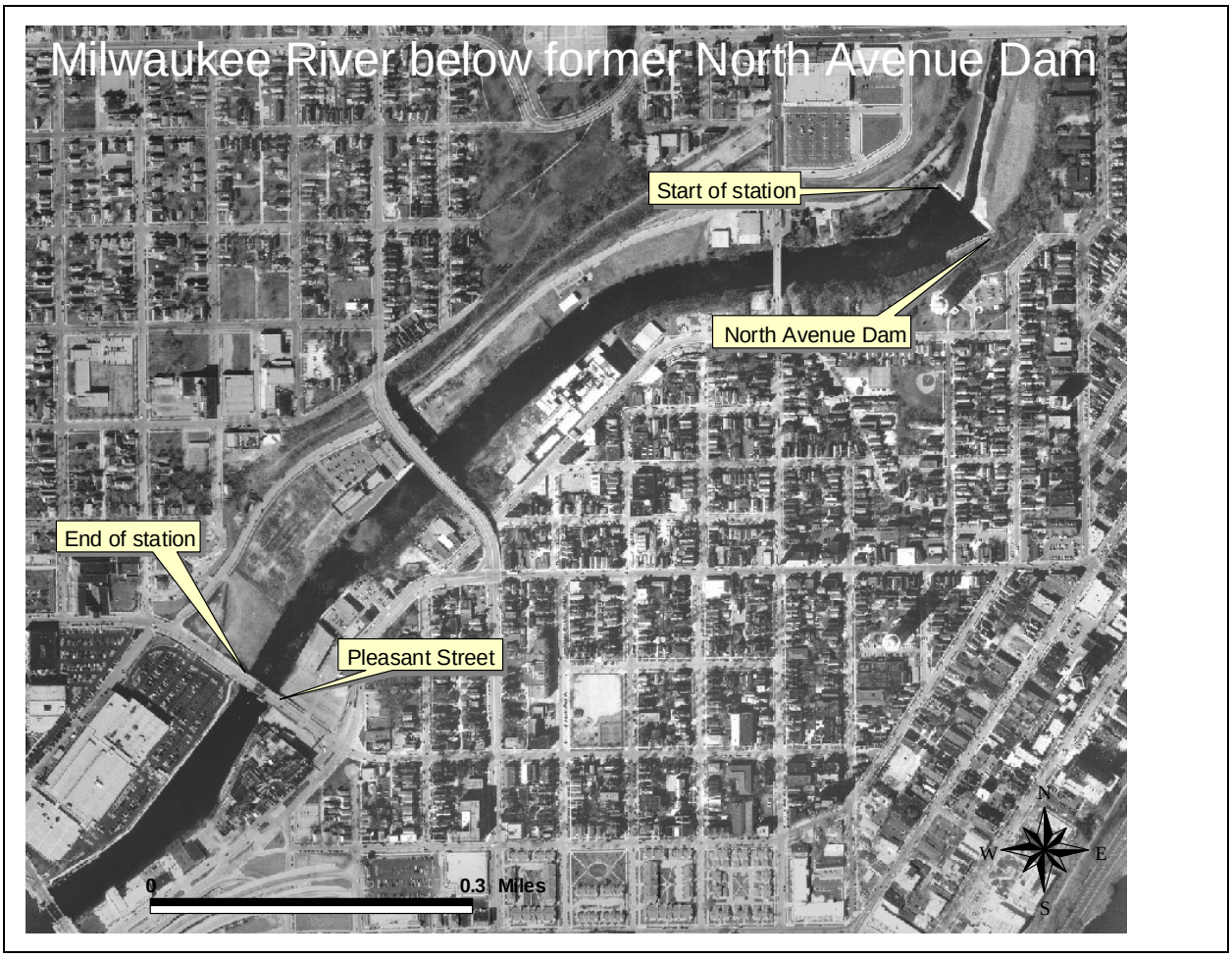

Figure 2. Milwaukee River downstream of the former North Avenue Dam.

3.2.2. Milwaukee River upstream of the former North Avenue Dam

Multiple stations were sampled between 1996 and 2001 during late summer. Some stations could not be sampled more than once (see Appendix 1). The Kletzsch Park station (the stretch between the Bender Road bridge and the Kletzsch Park Dam) and Capitol Drive station (the stretch between Chambers Street and the Capitol Drive bridge) were sampled multiple years from 1997 through 2001 (Figures 3—4 and 6-7). Therefore, we have used data for these two sites only to examine trends in the fish community. Smallmouth bass was selected as our target species in the study area because of their historical watershed distribution, their importance to Milwaukee River fishery management, and their associated water quality requirements.

3.2.2.1. Capitol Drive station

This section of the river represents the wadable portion of the former impoundment and thus was selected for long-term sampling to assess the fish community changes. The length of the river sampled was 1850 m (Figure 3). The width of the river varied from 40

to 70 meters. The river is quite wide in this stretch with very little over hanging tree cover. The substrate varied from cohesive silty-clay to gravel to large boulders. There were some areas of exposed fractured bedrock. The depth varied from < 0.3 meters to 1.2 meters. Much of the upstream portion of this site consisted of riffles, and the downstream portion was mostly runs (Figure 4). In this section we operated one two-anode and one three-anode 250 volt tow-barge DC-electroshockers simultaneously, one on each side of the river, moving upstream. This allowed for sampling across the entire stream width over the length of the station. Sampling at this location was conducted during day light hours. Fish tally and biological data were collected in same manner as above.

Figure 3. Fish sampling area between Locust Street bridge and Capitol Drive bridge (Capitol Drive station). Sampling area included 1850 m of stream section starting from Chambers Street to Capitol Drive bridge.

Figure 4. Capitol Drive sampling station.

3.2.2.2. Estabrook Impoundment station

This station represents the area impounded by the Estabrook Park Dam (Figure 5). Stream width varied from approximately 30 meters to 150 meters, with water depths from 1 meter to 4 meters. We used a mini boomshocker to sample this station. The total length of the impoundment, excluding side channels, is approximately 5,400 meters. The substrate consisted of silt, sand, and gravel, while fish cover was mainly in the form of deep holes, downed trees and riprap.

Figure 5. Estabrook Impoundment station.

3.2.2.3. Kletzsch Park station

Kletzsch Park is approximately 17 km upstream from the mouth of the Milwaukee River. Sampling was conducted from the Bender Road bridge upstream to the base of the Kletzsch Park Dam for a total of 460 meters (Figure 6). In the upstream-most 175 meters, we collected all species, and in the remaining area we collected only game species. Average stream width in this section is 30 meters, and depth ranges from < 0.3 meters to 1.2 meters. The flows were moderate, with riffles, runs and a few deeper pools. In addition to deeper pools, the fish cover consisted mainly of overhanging stream vegetation and some boulders (Figure 7). We used a two-anode 250-volt tow-barge DC-electroshocker to collect fish. Sampling generally occurred in mid-August each year. This site was historically not impounded by any of the dams in the study area.

Figure 6. Fish sampling area from Bender Road to Kletzsch Park Dam.

Figure 7. Kletzsch Park sampling station.

All fish were identified to species level, except some minnow species that were identified only to genus level. Non-game species were tallied, while game species were measured to the nearest millimeter and weighed to the nearest gram. Scale samples were taken from game species for age determination. Except for some small individuals

that were preserved as voucher specimens for identification confirmation, all other fish were returned to the river.

3.2.2.4. Brown Deer Road station

The Brown Deer Road station was sampled in 1996 with a mini boomshocker and in 1998 with a stream shocker. This station is located approximately 25 km from the mouth of the Milwaukee River, and 8.1 km upstream from the Kletzsch Park station. The station was approximately 400 meters in length, and began or ended at Brown Deer Road depending on the sampling gear (Figure 8). The substrate was predominantly sand and gravel, with scattered deposits of silt. Cover for fish consisted of deep pools and downed trees along the riverbank.

Figure 8. Brown Deer Road sampling station.

3.3. Data collection and analysis

Data collection occurred over a six-year period at multiple locations. Some locations were sampled less frequently than others (see Appendix 1) due to logistical constraints. Sampling generally occurred between June and October months at various locations depending on the weather conditions. Fish abundance data were summarized by species, location, and sampling year. The Capitol Drive and Kletzsch Park stations were sampled more consistently than the other stations. We compared the fish community from year to year within a sampling site and between sites. We calculated the index of biotic integrity (IBI) developed for wadable Wisconsin warmwater streams and rivers (Lyons 1992) to assess the overall environmental quality of these two stations. More emphasis was placed on the Capitol Drive station since it was previously impounded, and some habitat improvement measures were implemented in this area during the project period.

A detailed species-specific data analysis was conducted for smallmouth bass to examine population density, movement, recruitment, age and growth, and contribution to the nearshore fishery. Seasonal and spatial movement data on adult smallmouth bass were gathered by employing radiotelemetry. All equipment and transmitters were purchased from Advanced Telemetry Systems, Inc. in Isanti, Minnesota. We surgically implanted five adult smallmouth bass with radiotransmitters in May 2000 and five more in May 2001. These transmitters with unique frequencies were programmed to be “ON” for 12 hours and “OFF" for 12 hours on alternate weeks to maximize their battery life. The fish with implanted transmitters were released in geographically distant areas – Summerfest Lagoon, immediately downstream of the former North Avenue Dam, and in the inner Harbor by the University of Wisconsin’s WATER Institute (see Figure 16). Data on fish movement were collected by tracking from shore at various points along the river, and by canoe or boat.

3.4. Native species restoration

Because of the improving habitat conditions, efforts to restore a self-sustaining population of native walleye were initiated in 1995 with a goal to stock 10,000 extended growth walleye fingerlings annually in the Lower Milwaukee River. In 1995 and 1996, we used general walleye strain raised at the WDNR hatcheries. Beginning in 1998 the eggs were collected from Great Lakes strain walleye and raised at a DNR fish hatchery to extended growth fingerling size. These fingerlings (150mm-180mm total length) were marked to identify each year-class either by a fin clip or injecting an elastomer mark under the lower jaw. A sub-sample of 200 fingerlings were measured and checked for mark quality at the time of stocking (October). Data on growth, survival, spawning and population size were gathered through various annual assessments to evaluate the restoration effort. Radiotelemetry was used to monitor seasonal and spatial movement of adult walleye.

A Lake Sturgeon Management Plan has been developed to begin lake sturgeon restoration in Lake Michigan tributaries (WDNR 2000, GLFC 2005). Various life stages

(fry, fingerlings and yearlings) of sturgeon will be stocked annually in the Milwaukee River. In addition, some lake sturgeon will be PIT (Passive Integrated Transponder) tagged and implanted with radio transmitters to assess movement patterns in the river and Lake Michigan.

3.5. Habitat improvement

Several habitat improvement projects were initiated as part of the dam removal project. These projects included the stabilization of streambank using limestone riprap, building bendway weirs to direct flows, bioengineering techniques and installing of articulated concrete matting. Terra Engineering completed these projects for the City of Milwaukee as part of a restoration plan developed by the consulting firm of Camp, Dresser & McKee. In addition, the WDNR also had several projects to improve the habitat in these areas. These projects included augmenting the bendway weirs, placing boulder clusters in the river channel, streambank stabilization, livestaking the riverbank and partially cutting down willow trees for cover.

4.0. Results and discussion

4.1. Fish assemblages

This is the first extensive fish assemblage documentation following the removal of the North Avenue Dam in 1997. Data on species composition, number of fish captured, and catch per 1000 meters of effort, are summarized in several tables (Tables 1-11). Although multiple sites were sampled during a six-year period (1996-2001), only two index sites upstream of the former North Avenue Dam – Kletzsch Park and Capitol Drive stations – had more extensive long-term trend data.

4.1.1. Survey downstream of the former North Avenue Dam and Harbor

In our survey, a boom shocker was used exclusively to collect fish downstream of the Dam and in the harbor. Previous fish surveys conducted in the Milwaukee Harbor (Holey 1984) involved graded-mesh gill net, fyke nets and electroshocking. Sampling in the harbor has its own challenges due to high water conductivity, depth, and debris from flash floods, etc. The comprehensive survey data from Holey (1984) forms an important baseline fish distribution data prior to the North Avenue Dam removal, and helps to draw comparisons to current findings.

4.1.1.1. North Avenue Dam to Pleasant Street bridge station

In five years of sampling (Table 1), we recorded 20 native resident fish species, 2 trout species, migratory gizzard shad and alewife, and exotic carp species including common carp, grass carp and goldfish. There were a few unidentified minnow and redhorse species. We also documented the occurrence of the state-threatened greater redhorse in this section. White sucker was the most abundant species followed by golden

redhorse, common carp, and smallmouth bass. Recently stocked walleye appeared in the catches beginning in 1999.

4.1.1.2. Menomonee River and canals

The Menomonee River and the canals were sampled infrequently between 1997 and 2000, and produced fewer fish than other sampling sites (Table 2). A portion of the Menomonee River near Miller Park was sampled using a stream shocker, as the depth was not adequate for a boomshocker (Menomonee River #3, Figure 1). We found more minnow and sunfish species in this reach compared to downstream sites. The canals and lower Menomonee River (see Figure 1) produced greater variety of panfish and suckers (Table 2). Walleye captured were from the ongoing restoration effort. Because much of this area is channelized for shipping, and the canals have poor water circulation, the habitat and water quality is degraded. In addition, a warm water discharge into the river from an electric power company, and debris from storms further deteriorate water quality. Despite the poor water quality and the degraded habitat, we recorded a diverse fish community with sixteen native species.

4.1.1.3. Summerfest Lagoon

We sampled in the Summerfest Lagoon from 1997 to 2000. This protected body of water, bordered by the Henry Maier Festival Park grounds to the west, was formed by the creation of Harbor Island in 1991. The flow of water from the outer harbor into and out of the lagoon occurs through a channel along the shoreline at the north end and through culverts at the south end of the Harbor Island. The maximum depth of the lagoon is approximately 6 m. The riprap along the shoreline and thick submerged vegetation provide habitat for many species including smallmouth bass, largemouth bass, northern pike and panfish. The lagoon provides a unique year-round fishery, including winter ice fishing opportunities. In our survey, the number of fish species captured varied from six in 2000 to nineteen in 1997. In 1997, we recorded more than twice as many species compared to any other year. Smallmouth bass dominated the catch followed by white sucker and greater redhorse (Table 3). The rocky habitat around the island provides suitable habitat for smallmouth bass to flourish. We conducted a limited diving survey and documented smallmouth bass spawning activity. Radiotelemetry studies also indicated that both walleye and smallmouth bass use this area extensively throughout the year.

Although we recorded over twenty species in the harbor area and Menomonee River stations combined, the fish diversity was lower compared to the river sections upstream of the former North Avenue Dam. The harbor is dredged and may not provide much habitat diversity. Holey (1984) reported thirty-five species of fish, including stocked salmonids, in the Milwaukee River (downstream of the dam), dominated by carp, white suckers, greater redhorse, and alewife. Walleye of wide size ranges, indicating multiple year-classes, were caught in every month in the river below the North Avenue Dam during the survey. One of the possible reasons for recording fewer species in our study is that we used only a boom shocker (occasionally a stream shocker) in our survey as

opposed to the multiple types of sampling gear involved in the 1984 survey. Carp and suckers still dominate the catch, and larger carp were only recorded as present in our survey. The fish community may not have changed much in the harbor area since 1984, although the Summerfest Lagoon is a newer habitat.

In addition to above mentioned sites, we also sampled one time (1997) in Kinnickinnic River (Appendix 2) and one time at several locations in the harbor area (Appenidx 3).

4.1.2. Survey upstream of the former North Avenue Dam

4.1.2.1. Capitol Drive station

Two sites were selected as intensive study sites – Capitol Drive station (formerly impounded) and Kletzsch Park station (unimpounded) - for comparison of the fish assemblage, long-term changes in the fish assemblage, population characteristics, and index of biotic integrity.

There is no quantifiable information available on the fish community structure in the impoundment prior to dam removal. In August 1990, DNR biologists conducted a fish kill investigation in the impoundment which documented eight species – 6 native species and common carp and goldfish. Based on visual observation, common carp were the most abundant species, followed by white sucker. Black bullhead and goldfish were characterized as a common occurrence, and rock bass, green sunfish, shorthead redhorse, and fathead minnow were present. Following drawdown of the impoundment, we conducted a limited fish survey in 1996. We surveyed an 800-m stretch between Kern and Hubbard Parks, which is part of the Capitol Drive station. We captured 22 fish that belonged to seven native fish species. White sucker were the most abundant species with 32% of the catch, followed by rock bass (27%), smallmouth bass (14%), golden redhorse (9%), northern pike (9%), green sunfish (4.5%) and logperch (4.5%). Because of the wide width of the river, we could not effectively electrofish the area with a single stream shocker, which probably accounted for fewer fish captured and fewer species. In addition, only a third of the section was sampled compared to later years. However, compared to the number of species observed in 1990 and in 1996, it was a dramatic increase in the species diversity soon after drawdown.

From 1997 to 2001 we sampled the entire Capitol Drive station with two stream shockers running simultaneously, one on each side of the river. This allowed us to effectively sample the area consistently from year to year. Flow conditions were fairly uniform during the sampling window, and, for the most part, the sampling crew remained the same throughout the study period. Based on the combined five-year data set, we documented 37 species (Table 4), which included anadromous rainbow trout and coho salmon. Gizzard shad, though not a resident form, occurred in the sample as they migrated upstream from the lake. Goldfish was captured only once. Smallmouth bass, by number (sum of 1997 to 2001 catch), formed the most abundant species (38.6%), including young-of-the-year bass. The second most abundant species was rock bass (14%), followed by white sucker (7.7%), stoneroller (7.3%), johnny darter

(5.8%), horny head chub (3%), shorthead redhorse (2.9%), bluntnose minnow (2.8%), green sunfish (2%) and golden redhorse (2%). The remaining species each contributed less than 2% to the total catch. Twelve species (common carp, spottail shiner, sand shiner, bluntnose minnow, white sucker, golden redhorse, shorthead redhorse, greater redhorse, rock bass, green sunfish, smallmouth bass, and johnny darter) occurred in the sample all five years. It is important to note that a state-threatened species, greater redhorse, occurred in all the samples, and the catch per 1000 m varied from 7.3 fish in 2000 to 46.3 fish in 1998 (Table 5). Besides smallmouth bass, stoneroller, johnny darter, white sucker and rock bass occurred at consistently large numbers from year to year. Smallmouth bass had very successful hatches in 1998, 2000 and 2001, as evidenced by the large number of young-of-the-year captured in those years. Although we did not notice any pattern or trend in the reestablishment of the fish assemblage in the previously impounded stretch, it appeared that a diverse fish community established fairly quickly with as many as twenty-one native fish species by 1997.

4.1.2.2. Estabrook Impoundment

The Estabrook Impoundment station is located from Bender Road downstream to the Estabrook Park Dam (Figures 1 & 5). The water level in the impoundment varies based on dam operation. We sampled in the impounded area (approximately 5200-m stretch) with a miniboom in 2000 and 2001. A total of 23 species were documented during two years of sampling. Golden redhorse was the most abundant species, followed by spotfin shiner and smallmouth bass (Table 6). We also documented the state-threatened species greater redhorse in both years.

4.1.2.3. Kletzsch Park station

The Kletzsch Park station is an upstream site, which was not influenced by the North Avenue Dam impoundment. The upstream end of the station is fast flowing riffle, immediately downstream of the Kletzsch Park Dam (see Figure 5). The downstream section has some deep holes, and glides with overhanging tree branches, large boulders, and undercut banks providing fish cover. We recorded a total of 29 native species in five years of sampling, ranging from 11 species in 1996 to 23 species in 2001 (Table 7). We could not sample this section in 1997 due to logistical reasons. Common carp was the only exotic species captured. The few walleye that were captured belonged to the recent stocking effort, demonstrating that the stocked walleye swim past the Estabrook Falls and Dam. Almost all the species captured at this station were also found in the Capitol Drive station except an occasional brassy minnow and fantail darter. At least seven species occurred consistently in all samples – spotfin shiner, common shiner, sand shiner, bluntnose minnow, rock bass, smallmouth bass, and logperch – although the numbers differed from year to year. Based on the five year total, sand shiner dominated the catch by number (19%) followed by smallmouth bass (15%), common shiner (8.5%), golden redhorse (8%), logperch (7.7%), shorthead redhorse (7%), greater redhorse (6%), rock bass (5%), spotfin shiner (4%), stoneroller (2.3%), and bluntnose minnow (2%). The remaining species contributed less than 2% of the total fish captured. The catch per 1000 m of river for greater redhorse was much

greater in this station in 1998 and 1999 (Table 8) compared to the Capitol Drive station (Table 7). We captured fewer smallmouth bass per 1000 m compared to the Capitol Drive station, and most of the smallmouth bass were ages 1 and 2.

4.1.2.4 Brown Deer Road station

We sampled the Brown Deer Road station in 1996 and 1998. This station, which is upstream of the Kletzsch Park station, extended from the Brown Deer Road bridge 400 m downstream. In this location, hanging tree branches, deep holes, and sandbars in the river channel made sampling quite challenging. However, we documented a total of fifteen species, with the majority of them being cyprinids and centrarchids (Table 9). Sand shiner was the most abundant species followed by green sunfish, smallmouth bass and golden redhorse. Occasionally, northern pike were found in deeper water, especially in the deeper pools with abundant woody cover. We discontinued sampling here due to logistical difficulties.

4.2. Index of Biotic Integrity (IBI)

In our study, we recorded a major change in the fish assemblage in the previously impounded area after the North Avenue Dam was removed in 1997. In the 1990 survey (a fish kill investigation), the total number of native and non-native fish species was less than ten (Figure 9a). Since 1997 the total number of native species in the formerly impounded Capitol Drive station has ranged from 21 in 1997 to 31 in 2001. The number of non-native species ranged from 1 to 3 (Figure 9a) at Capitol Drive station, while it was only common carp at Kletzsch Park station (Figure 9b).

Lyons (1992) developed a fish-based IBI for Wisconsin's warmwater streams. The Index of biotic integrity (IBI) is often used to measure overall aquatic environmental health based on the structure and composition of aquatic communities (Fausch et al. 1990). The main application of large-river IBI, according to Lyons et al. (2001), is the ability to rapidly assess ecosystem quality and to evaluate specific management needs to restore river ecosystems. This tool is applicable to the Lower Milwaukee River, where the ecosystem had been dramatically altered due to damming for decades and dam removal has occurred recently. Secondly, Lyons et al. (2001) recommended multiple years of sampling in order to document trends in ecosystem characteristics. We were able to collect data from our index sampling stations (Capitol Drive station and Kletzsch Park station) from 1996 to 2001 using a single sampling procedure, and during the same time period in similar flow conditions. The IBI scores at Capitol Drive station ranged from 20 (Poor) in 1996, 57-62 (Good) in 1997 and 1998, 70-80 (Excellent) in 1999-2001 (Figure 10a). The increase in IBI scores since 1997 coincides with the time period when the dam was completely removed, and habitat improvement measures were implemented. The number of native species with individuals of all sizes and ages also increased with time. The greater redhorse, which is a state listed threatened fish species, occurred consistently in the sample since 1997 (Table 4).

The IBI scores at Kletzsch Park station ranged from 54 (Good) in 1996 to 65-80 (Excellent) in 1998-2001 indicating excellent environmental quality at this station (Figure 10b). Compared to this station, which was not impacted by the impoundment, the Capitol Drive station recovered quite fast and approached IBI scores of Kletzsch Park station, indicating improved environmental quality.

4.3. Smallmouth bass population

In this survey, smallmouth bass were captured at all of the sites sampled in the Lower Milwaukee River and Harbor. Smallmouth bass occur in all drainage basins in Wisconsin (Becker 1983). They are common in medium to large streams, inhabiting the warmer sections of the stream, and are often taken from streams with varying currents. Both Kletzsch Park and Capitol Drive stations had varying degrees of current, with riffles and pools. The water temperature ranged from 66 ^{0}F to 80 ^{0}F at Kletzsch Park station and 57 ^{0}F to 73 ^{0}F at Capitol Drive station. Although the river at Kletzsch Park station is narrower than the Capitol Drive station, it has some deeper pools and undercut banks suitable for smallmouth bass. Both sites have large boulders, rubble, and gravel associated with strong riffles toward the upper end of the stations. The upper end of Kletzsch Park station culminates in a small dam and waterfall (about 2m high), creating a deep pool below the dam.

At the formerly impounded Capitol Drive station, we documented smallmouth bass of several year classes indicating successful recruitment (Figure 11). Catch per 1000m of stream section (CPUE), for all age groups combined, varied from 35.7 fish in 1997 to 504.3 fish in 2000 (Table 5). Large year-classes were produced in 1998, 2000 and 2001 (Table 10, Figure 11). A similar observation was made by Kanehl et al. (1997) where smallmouth bass abundance and biomass increased dramatically following removal of the Woolen Mills Dam from the Milwaukee River.

The YOY (young-of-the-year) CPUE at Capitol Drive station (Table 10) was the greatest in 2000 (259.5 YOY), and the lowest in 1997 (32.4 YOY). Each year we collected scale samples from a subsample of smallmouth bass across different size classes for age determination. Because of the small sample size, we lumped all of age 1 and older fish for calculation of CPUE. We did not age any YOY smallmouth bass from the 2000 sample (YOY catch in 2000 was determined based on length-frequency data). The survival of YOY smallmouth bass and year-class strength in this stretch of river water may be affected by the flows regulated by Estabrook Dam operation, which is upstream. The water temperature was much cooler in 2000 (57 ^{0}F) compared to other years. Although 2000 produced a large number of YOY smallmouth bass, they did not appear in sizable numbers in 2001 (Table 11, Figure 11). However, the 1998 year-class appeared to have survived better and consistently dominated the catch in 1999 and in 2000. This contributed to the higher CPUE of age 1 and older bass in 1999 and 2000.

The proportion of age 3 and older smallmouth bass in the sample dwindled from year to year (Table 11). This may be a function of flow conditions, movement of fish, or fishing pressure. It is possible that larger, older bass may seek deeper water or move

downstream. In general, the increase in the abundance of smallmouth bass in the area was mainly due to recruitment rather than immigration.

The average size of 1998 YOY smallmouth bass from the Capitol Drive station was greater (118mm) than the other year-classes (Table 11). The average sizes of 1998 year-class were 161 mm (age 1) and 222 mm (age 2) in 1999 and 2000, respectively. In contrast, the 2000 year-class smallmouth bass were much smaller in 2001 (age 1), averaging only 145 mm (Table 12). The cooler average water temperature in 2000 may have had some impact on the growth of the YOY smallmouth bass. Kroeff (1996) recorded back-calculated lengths of age 1 smallmouth bass averaging 120 mm to 127 mm at different sites along Door County shoreline, WI. The average annual increment in growth for ages one through five for these smallmouth bass was 45 mm. Based on the size-at-age data for this station (Table 11, Figure 12), the growth rate of smallmouth bass in the Lower Milwaukee River appears to be greater than the Sturgeon Bay population in Door County. The average annual increment was 50 mm for ages one through four at Capitol Drive station, 62 mm at Kletzsch Park station for ages one and two, and 73 mm for ages two through five at the Summerfest Lagoon station (1998 data, Figures 12-14). (We used size-at-age at capture, not back-calculated length.) A steady supply of forage in the Harbor (plenty of crayfish and other food) might contribute to the higher growth rate in this area. Warmer water in the Menomonee River canal could also impact growth of these bass, as they appear to be freely moving in the area, demonstrated by radiotelemetry.

A large number of YOY smallmouth bass were also produced at the Kletzsch Park station in 1998 and 2000 (Figure 15). Despite the smaller average size of 1998 YOY bass (73mm) compared to those at the Capitol Drive station, the 1998 year-class survived well and was present in our samples in large numbers as ages 1, 2 and 3 (Table 13). Although the number and CPUE of smallmouth bass captured at the Kletzsch Park station were lower than the Capitol Drive station, we did document multiple year-classes each year (Table 13), indicating good recruitment. By and large, the 1998 year-class was the strongest at each station probably due to warmer water temperature (80^0F) than other sampling years.

4.4. Smallmouth bass movement

Removal of the North Avenue Dam eliminated the impediment for smallmouth bass to move between the estuary and upriver which has expanded the potential fishing area. However, we do not have a good understanding of movement of adult smallmouth bass in the Lower Milwaukee River and Harbor. Tagging bass using Floy anchor tags has generated only a limited amount of data on the movements of smallmouth bass in the area.

Therefore, in order to determine seasonal movement patterns and spawning locations of bass we employed radiotelemetry. Ten adult smallmouth bass were surgically implanted with radio transmitters in 2000 and 2001. These transmitters were programmed to be “ON” for 12 hours and “OFF” for 12 hours on alternate weeks to

maximize their battery life. They were released in geographically distant areas – Summerfest Lagoon, immediately downstream of the former North Avenue Dam, and in the Inner Harbor near the University of Wisconsin's WATER Institute.

Based on the data collected (Figure 16) it appears that smallmouth bass move between the harbor and the lower Milwaukee River, as far upstream as Kletzsch Park. We found radiotagged smallmouth bass in the South Shore harbor and McKinley Marina. We did not notice any clear seasonal pattern in their movement, nor distinct upstream-downstream movement. The majority of the time these adult smallmouth bass were found in the Summerfest Lagoon. We documented many smallmouth bass nests in the lagoon and the South Shore Marina. The rocky habitat and gravel bottom covered with rooted submerged vegetation offers suitable habitat for smallmouth bass. We were able to collect some young of the year smallmouth bass while seining at South Shore Marina in late summer, indicating potential spawning habitat.

4.5. Population restoration

4.5.1. Walleye restoration project

Walleye, native to the Milwaukee River, were almost extirpated in the Lower Milwaukee River due to altered habitat conditions caused by damming. The removal of the North Avenue Dam opened up an additional 11.3 km of river section, from the former North Avenue Dam to the Kletzsch Park Dam, for native species. The Lower Milwaukee River flows through a predominantly urban environment before draining into Lake Michigan. As a result of improved environmental conditions, coupled by a decline in the Lake Michigan yellow perch population in the 1990's, there was a renewed interest in the restoration of walleye to augment nearshore-fishing opportunities.

In the past, WDNR attempted to restore the walleye population by stocking millions of fry. Fry stocking did not prove to be successful. Starting in 1995, with initial funding from local nearshore fishing clubs, WDNR stocked 10,000 extended growth walleye fingerlings in the Lower Milwaukee River immediately downstream of the former North Avenue Dam (Hirethota and Burzynski 2004). Since the extended growth walleye fingerlings survived better and grew well, WDNR developed a walleye population restoration plan to continue stocking through 2004 (WDNR 1998). Per this plan, approximately 10,000 Great Lakes strain extended growth walleye fingerlings were stocked annually in the river (Table 14). Some years we could not meet the goal of stocking 10,000 fingerlings due to unforeseen circumstances. The main goal of the project was to develop a self-sustaining walleye population in the Lower Milwaukee River and Harbor, while ensuring minimal impact on stocked Chinook salmon smolts. These large walleye fingerlings were marked using either a fin clip or visible implant elastomer (VIE) to identify year-class (Table 14) (Thompson et al. 2005).

We conducted population estimates based on a mark-recapture method using all walleye captured (both adults and sub-adults). The most recent estimate of walleye in 2005 was 506 (95% confidence interval of 256 and 1,190) walleye in the Lower

Milwaukee River (Table 15). Due to availability of abundant prey species such as gizzard shad, shiners, stickleback, etc. the growth rates of these stocked walleye (Figure 17) appear to be greater than the state average (Figure 18). While growth rates have been excellent, no natural reproduction has been detected. However, annual spring spawning surveys documented several spent and mature male and female walleye in the upstream waters of the Milwaukee River. Data on predatory impact of these stocked walleye on stocked salmonid smolts revealed no negative impact (Hirethota and Burzynski 2004).

There appears to be fair amount of targeted fishing effort for walleye in the area (Table 16). Prior to stocking (1995), directed effort for walleye were low and almost exclusively by shore anglers. Since 1995, the directed effort in all fishery types has increased. Due to more public interest on the walleye fishery in recent years, the effort has increased (2003 to present) to over 1,000 hours for shore anglers, 600 hours for anglers upstream of the dam and 800 hours for anglers fishing in the Menomonee River and canals. Overall, angler response is positive in that the nearshore angling community has an opportunity to fish once again for a species that had nearly disappeared from the area.

4.5.2. Lake sturgeon restoration project

The Wisconsin Department of Natural Resources has developed a Lake Sturgeon Management Plan for the entire state. As part of this plan, certain Lake Michigan tributaries have been identified in the priority list of Wisconsin Lake Sturgeon Rehabilitation waters. These waters include the Milwaukee and Manitowoc Rivers. The main goals of the rehabilitation of lake sturgeon in the Milwaukee River are to enhance their population, understand their life history requirements, and identify critical habitat and barriers to migration.

The first stocking of lake sturgeon in the Milwaukee River occurred in May 2003 with the stocking of 51,000 larvae, and an additional 13,000 larvae in June 2003. Juveniles from the Wolf River were transferred and stocked in November 2003, and 7 of the 8 juveniles were radio tagged (Table 17). In addition, 200 yearlings were PIT tagged and fin clipped and then stocked in June 2004.

Recently, both juvenile/adult sturgeon from the Wolf River and fingerlings were stocked in fall 2004. Six of the adults were radio tagged (Table 17) and two were determined to be sexually mature. In May 2005, another 100 yearlings were stocked at Lime Kiln Park, Grafton, WI. Those stockings represent the start of a long rehabilitation program for lake sturgeon in the Milwaukee River. Wisconsin DNR plans to continue to monitor the movement patterns of all lake sturgeons stocked. In addition, extensive habitat surveys at selected sites in the Milwaukee River will be evaluated and described. These locations will correspond to juvenile nursery areas and potential adult spawning locations.

4.6. Habitat improvement

The North Avenue Dam, constructed in 1835, destroyed the fish habitat both in the impoundment area and the area immediately downstream due to decades of deposits of silt and chemical wastes. In addition, the lower reaches of the Milwaukee River and its estuary were dredged to accommodate commercial shipping. In 1996, when the dam was partially removed, a decision was made to restore the river section that was formerly impounded. Terra Engineering, the contractor, placed a series of bendway weirs and boulder clusters to direct flows away from banks and to provide cover and habitat for fish and invertebrates. In addition, the river channel between the dam and the North Avenue bridge was armored with articulated concrete matting to prevent down-cutting and hold sediment in place.

WDNR Fisheries staff added to the work initiated in the original project. A total of 127 large, flat stones were placed over a distance of 204 meters (670 feet) on top of the articulated concrete matting in the river channel using an overhead crane. A Caterpillar 307 excavator was used to augment the bendway weirs. Fieldstone boulders were placed in the stream channel by boat, either individually or in clusters to provide cover for fish, both resident and migratory species. Also, approximately 90 meters of riverbank was livestaked, and 30 willow trees were used as bank cover. We believe these measures have benefited native species such as smallmouth bass, as well as anadromous salmon and trout. However, more work is needed to enhance spawning and nursery habitat for native species.

Future work includes the *Milwaukee River Estuary Fish Spawning Habitat Rehabilitation Project,* which proposes to plan, design and install fish spawning habitat for native resident and potadromous fish, and other aquatic life in the Milwaukee River Estuary. The project area is located immediately downstream of the former North Avenue Dam. Based on photographs from the late 1800's, the dam was constructed on a rock riffle. This critical spawning habitat was destroyed in the early 1900's as the lower reaches of the Milwaukee River and its estuary were dredged to accommodate commercial shipping. The proposed 2-year work plan includes initial data gathering on depth, substrate texture, current direction, velocity, and extent of periphyton in this area, which will provide insight into design and construction of spawning habitat. Plans for habitat improvements will then be designed, and implemented.

5.0. Management implications

A long-term evaluation such as this provides valuable information on both the current status and trend of the fish community in the study area. Our data indicated significant changes in the fish assemblage in the previously impounded area (Capitol Drive station). The increase in the number of species found may be attributed to changes in habitat quality. The IBI scores increased from 1996 to 2001 following dam removal, indicating improved environmental quality. The number of native fish species increased greatly, including a state listed threatened species (greater redhorse). The greater number of smallmouth bass, both young and adults, in this section is a function of

available suitable habitat rather than immigration to the area. Dam removal remains a high priority within the Department with many removals occurring in the past decade in Southeastern Wisconsin (North Avenue, Waubeka, Woolen Mills, Chair Factory, Franklin, Schweitzer, Hamilton, Young America, Falk and 43rd Street drop structure on the Menomonee River). Numerous studies, including this current study, have shown the benefits to the fish community following dam removal. Other dams on the Milwaukee River including Estabrook, Kletzsch and Thiensville should be studied to see if removal or fish passage can be accomplished with minimal impact to the environment and conflicts with different user groups in those areas.

A change from a lentic system to a lotic system would take some time to stabilize. This section of the river, which was impounded for several decades, had limited structural diversity. Human effort to add structural diversity to the channel seemed to increase biological diversity. It is difficult to extrapolate the benefit of stream habitat improvement measures that were implemented. However, addition of instream structure and bank stabilization measures added to the complexity of structure and fish cover for both resident as well as migratory species. Dam removal and habitat improvements are key fisheries management tools that are pivotal if native species are to be restored in these once degraded areas. Because of the dam removal, Wisconsin DNR initiated two native species restoration plans, walleye and lake sturgeon, in the Milwaukee River Estuary. These restoration efforts help to develop a more vital and diverse fish community. In addition, the removal of the North Avenue Dam has significantly enhanced fishing opportunities by opening up several river miles for migratory salmonids and resident native species.

Operation of the Estabrook Dam, upstream of the Capitol Drive station, appears to have significant impact on the year-class strength of smallmouth bass and obstructs the movement of fish further upstream. In this study, both sharp increase and decrease in water flow attributable to current Estabrook Dam operations, appears to have caused negative impacts to several year-classes of smallmouth bass. In order to maximize the benefits of the dam removal and habitat enhancements in the lower Milwaukee River, the Estabrook dam and it's operation will need to be addressed.

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Table 1. Number of fish captured by species at the North Avenue Dam station, Milwaukee River.

Family and species	YEAR					
	1996	1997	1999	2000	2001	Total
Amiidae						
Bowfin *Amia calva*	1					1
Clupeidae						
Alewife *Alosa pseudoharengus*		65		1		66
Gizzard shad *Dorosoma cepedianum*	500	137	2	254		893
Salmonidae						
Rainbow trout *Oncorhynchus mykiss*				4		4
Brown trout *Salmo trutta*				3		3
Esocidae						
Northern pike *Esox lucius*		4	1	12	3	20
Cyprinidae						
Goldfish *Carassius auratus*	1	1				2
Grass carp *Ctenopharyngodon idella*	1					1
Spotfin shiner *Cyprinella spiloptera*		1				1
Common carp *Cyprinus carpio*	32	11		11		54
Golden shiner *Notemigonus crysoleucas*	1		1			2
Emerald shiner *Notropis atherinoides*				1		1
Minnows & Carps unsp.		1				1
Catostomidae						
White sucker *Catostomus commersoni*		1		140		141
Redhorse spp. *Moxostoma spp.*	25	21				46
Silver redhorse *Moxostoma anisurum*				9		9
Golden redhorse *Moxostoma erythrurum*		37	6	21		64
Shorthead redhorse *Moxostoma macrolepidotum*			2	3		5
Greater redhorse *Moxostoma valenciennesi*				19		19
Ictaluridae						
Black bullhead *Ameiurus melas*		1				1
Percopsidae						
Trout-perch *Percopsis omiscomaycus*				1		1
Centrarchidae						
Rock bass *Ambloplites rupestris*	3	1		1		5
Green sunfish *Lepomis cyanellus*	2	1		1		4
Pumpkinseed *Lepomis gibbosus*	1		1			2
Bluegill *Lepomis macrochirus*	7	3		1		11
Smallmouth bass *Micropterus dolomieu*	12	16	3	5		36
Largemouth bass *Micropterus salmoides*		2	1			3
Percidae						
Yellow perch *Perca flavescens*		1		2		3
Walleye *Sander vitreus*			2	24	6	32

Table 2. Number of fish captured by species in the Menomonee River and Canals.

Family and species	YEAR				
	1997		1999	2000	Total
	MNR1	MNR2	MNR3	MNRCNL	
Clupeidae					
Gizzard shad *Dorosoma cepedianum*	7				7
Salmonidae					
Brown trout *Salmo trutta*			1		1
Cyprinidae					
Common carp *Cyprinus carpio*	9		1		10
Common carp x Goldfish	1				1
Spottail shiner *Notropis hudsonius*	1				1
Bluntnose minnow *Pimephales notatus*			1		1
Fathead minnow *Pimephales promelas*			18		18
Blacknose dace *Rhinichthys atratulus*			19		19
Creek chub *Semotilus atromaculatus*			23		23
Catostomidae					
White sucker *Catostomus commersoni*			38		38
Redhorse spp. *Moxostoma spp.*	1				1
Golden redhorse *Moxostoma erythrurum*	4				4
Greater redhorse *Moxostoma valenciennesi*	8				8
Ictaluridae					
Black bullhead *Ameiurus melas*	1		5		6
Centrarchidae					
Green sunfish *Lepomis cyanellus*	11	1	25	2	39
Green sunfish x Pumpkinseed	2		3		5
Pumpkinseed *Lepomis gibbosus*	2				2
Pumpkinseed x Bluegill	3				3
Bluegill *Lepomis macrochirus*	5	1		7	13
Smallmouth bass *Micropterus dolomieu*				6	6
Largemouth bass *Micropterus salmoides*	3			19	22
Sunfishes *Lepomis & Ambloplites*				4	4
Percidae					
Johnny darter *Etheostoma nigrum*			1		1
Walleye *Sander vitreus*				8	8

Site codes (see Appendix 1):

MNR1= Menomonee River from 16th Street to 26th Street
MNR2= Menomonee River from 6th Street to I-94
MNR3= Miller Park (35th Street to I-94)
MNRCNL= Menomonee River Canals

Table 3. Number of fish captured by species in the Summerfest Lagoon, Milwaukee Harbor.

Family and species	YEAR				
	1997	1998	1999	2000	Total
Clupeidae					
Alewife *Alosa pseudoharengus*	12				12
Gizzard shad *Dorosoma cepedianum*	2		1		3
Salmonidae					
Brown trout *Salmo trutta*	14	2	1		17
Esocidae					
Northern pike *Esox lucius*	1			5	6
Cyprinidae					
Common carp *Cyprinus carpio*	8				8
Catostomidae					
White sucker *Catostomus commersoni*	55	6	3		64
Redhorse spp. *Moxostoma spp.*		1			1
Golden redhorse *Moxostoma erythrurum*	14				14
Shorthead redhorse *Moxostoma macrolepidotum*			4		4
Greater redhorse *Moxostoma valenciennesi*	29		2		31
Ictaluridae					
Black bullhead *Ameiurus melas*	1	1			2
Gasterosteidae					
Threespine stickleback *Gasterosteus aculeatus*	4				4
Centrarchidae					
Rock bass *Ambloplites rupestris*	1				1
Green sunfish *Lepomis cyanellus*	4				4
Pumpkinseed *Lepomis gibbosus*	20	3		3	26
Bluegill *Lepomis macrochirus*	13				13
Smallmouth bass *Micropterus dolomieu*	94	14	1	3	112
Largemouth bass *Micropterus salmoides*	7	5	4	11	27
Black crappie *Pomoxis nigromaculatus*	1		1	1	3
Percidae					
Walleye *Sander vitreus*	5	2		6	13
Cottidae					
Sculpin spp.	1				1

Table 4. Number of fish captured by species from 1997 – 2001 Capitol Drive station - Milwaukee River.

Family and species	YEAR					
	1997	1998	1999	2000	2001	Total
Clupeidae						
Gizzard shad *Dorosoma cepedianum*		7			1	8
Salmonidae						
Coho salmon *Oncorhynchus kisutch*	4					4
Rainbow trout *Oncorhynchus mykiss*	2					2
Esocidae						
Northern pike *Esox lucius*	3	4			5	12
Cyprinidae						
Central stoneroller *Campostoma anomalum*		7			8	15
Largescale stoneroller *Campostoma oligolepis*		1		5	99	105
Stoneroller spp. *Campostoma spp.*	233		182	10	25	450
Goldfish *Carassius auratus*		1				1
Spotfin shiner *Cyprinella spiloptera*			9	47	27	83
Common carp *Cyprinus carpio*	15	P	P	P	13	28
Common shiner *Luxilus cornutus*	3	2	5	10	16	36
Hornyhead chub *Nocomis biguttatus*	3		15	113	55	186
Emerald shiner *Notropis atherinoides*			20	2	7	29
Spottail shiner *Notropis hudsonius*	5	1	6	5	7	24
Sand shiner *Notropis stramineus*	18	2	7	70	142	97
Mimic shiner *Notropis volucellus*					45	10
Shiners unsp. *Notropis spp.*				3	19	22
Bluntnose minnow *Pimephales notatus*	25	16	23	64	42	170
Fathead minnow *Pimephales promelas*	1			7	1	9
Minnows & Carps unsp.	1				3	4
Catostomidae						
White sucker *Catostomus commersoni*	132	35	24	101	180	472
Silver redhorse *Moxostoma anisurum*		1		4	13	18
Golden redhorse *Moxostoma erythrurum*	19	14	19	40	38	130
Shorthead redhorse *Moxostoma macrolepidotum*	28	4	51	37	59	179
Greater redhorse *Moxostoma valenciennesi*	11	19	15	3	17	65
Ictaluridae						
Black bullhead *Ameiurus melas*	3	1			7	11
Yellow bullhead *Ameiurus natalis*	1				3	4
Bullhead catfishes *Ameiurus spp.*			1			1
Channel catfish *Ictalurus punctatus*					15	15
Stonecat *Noturus flavus*		2	1	2	18	23
Centrarchidae						
Rock bass *Ambloplites rupestris*	41	93	309	127	306	876
Green sunfish *Lepomis cyanellus*	95	15	19	2	2	133
Pumpkinseed *Lepomis gibbosus*		7	4	1	2	14
Bluegill *Lepomis macrochirus*		5	2	1	8	16
Smallmouth bass *Micropterus dolomieu*	66	521	357	933	479	2356
Largemouth bass *Micropterus salmoides*	2	33	3	1	8	47
Black crappie *Pomoxis nigromaculatus*		1	1		1	3
Percidae						
Johnny darter *Etheostoma nigrum*	231	1	1	12	112	357
Logperch *Percina caprodes*	11	7	33		5	56
Blackside darter *Percina maculata*	7	1				8
Walleye *Sander vitreus*		1	1	5	4	11

Table 5. Catch per unit effort (per 1000-m stretch) of fish captured by species from 1997 – 2001 at Capitol Drive station - Milwaukee River.

Family and species	YEAR				
	1997	**1998**	**1999**	**2000**	**2001**
Clupeidae					
Gizzard shad *Dorosoma cepedianum*		17.1			2.4
Salmonidae					
Coho salmon *Oncorhynchus kisutch*	2.2				
Rainbow trout *Oncorhynchus mykiss*	1.1				
Esocidae					
Northern pike *Esox lucius*	1.6	2.2			2.7
Cyprinidae					
Central stoneroller *Campostoma anomalum*		17.1			19.5
Largescale stoneroller *Campostoma oligolepis*		2.4		12.2	241.5
Stoneroller spp. *Campostoma spp.*	568.3		443.9	24.4	61
Goldfish *Carassius auratus*		2.4			
Spotfin shiner *Cyprinella spiloptera*			22	114.6	65.9
Common carp *Cyprinus carpio*	36.6	P	P	P	31.7
Common shiner *Luxilus cornutus*	7.3	4.9	12.2	24.4	39
Hornyhead chub *Nocomis biguttatus*	7.3		36.6	275.6	134.1
Emerald shiner *Notropis atherinoides*			48.8	4.9	17.1
Spottail shiner *Notropis hudsonius*	12.2	2.4	14.6	12.2	17.1
Sand shiner *Notropis stramineus*	43.9	4.9	17.1	170.7	142
Mimic shiner *Notropis volucellus*					109.8
Shiners unsp. *Notropis spp.*				7.3	46.3
Bluntnose minnow *Pimephales notatus*	61	39	56.1	156.1	102.4
Fathead minnow *Pimephales promelas*	2.4			17.1	2.4
Minnows & Carps unsp.	2.4				7.3
Catostomidae					
White sucker *Catostomus commersoni*	322	85.4	58.5	246.3	439
Silver redhorse *Moxostoma anisurum*		2.4		9.8	31.7
Golden redhorse *Moxostoma erythrurum*	46.3	34.1	46.3	97.6	92.7
Shorthead redhorse *Moxostoma macrolepidotum*	68.3	9.8	124.4	90.2	143.9
Greater redhorse *Moxostoma valenciennesi*	26.8	46.3	36.6	7.3	41.5
Ictaluridae					
Black bullhead *Ameiurus melas*	1.6	0.5			3.8
Yellow bullhead *Ameiurus natalis*	0.5				1.6
Bullhead catfishes *Ameiurus spp.*			0.5		
Channel catfish *Ictalurus punctatus*					8.1
Stonecat *Noturus flavus*		1.1	0.5	1.1	9.7
Centrarchidae					
Rock bass *Ambloplites rupestris*	22.2	50.3	167	68.6	165.4
Green sunfish *Lepomis cyanellus*	51.4	8.1	10.3	1.1	1.1
Pumpkinseed *Lepomis gibbosus*		3.8	2.2	0.5	1.1
Bluegill *Lepomis macrochirus*		2.7	1.1	0.5	4.3
Smallmouth bass *Micropterus dolomieu*	35.7	281.6	193	504.3	258.9
Largemouth bass *Micropterus salmoides*	1.1	17.8	1.6	0.5	4.3
Black crappie *Pomoxis nigromaculatus*		0.5	0.5		0.5
Percidae					
Johnny darter *Etheostoma nigrum*	563.4	2.4	2.4	29.3	273.2
Logperch *Percina caprodes*	26.8	17.1	80.5		12.2
Blackside darter *Percina maculata*	17.1	2.4			
Walleye *Sander vitreus*		0.5	0.5	2.7	2.2

Table 6. Number of fish captured by species at Estabrook Impoundment, Milwaukee River.

Family and species	YEAR		
	2000	2001	Total
Clupeidae			
Gizzard shad *Dorosoma cepedianum*	16		16
Esocidae			
Northern pike *Esox lucius*	4	1	5
Cyprinidae			
Spotfin shiner *Cyprinella spiloptera*	70		70
Common carp *Cyprinus carpio*	21		21
Common shiner *Luxilus cornutus*	14	2	16
Spottail shiner *Notropis hudsonius*	1		1
Sand shiner *Notropis stramineus*	20		20
Bluntnose minnow *Pimephales notatus*	2		2
Minnows & Carps unsp.	12		12
Catostomidae			
White sucker *Catostomus commersoni*	2	6	8
Silver redhorse *Moxostoma anisurum*	35	7	42
Golden redhorse *Moxostoma erythrurum*	72	36	108
Shorthead redhorse *Moxostoma macrolepidotum*	24	3	27
Greater redhorse *Moxostoma valenciennesi*	3	14	17
Ictaluridae			
Yellow bullhead *Ameiurus natalis*	1		1
Stonecat *Noturus flavus*	1		1
Cyprinodontidae			
Blackstripe topminnow *Fundulus notatus*	1		1
Centrarchidae			
Rock bass *Ambloplites rupestris*	26	1	27
Green sunfish *Lepomis cyanellus*	1		1
Pumpkinseed *Lepomis gibbosus*	3		3
Bluegill *Lepomis macrochirus*	5		5
Smallmouth bass *Micropterus dolomieu*	53	7	60
Largemouth bass *Micropterus salmoides*		2	2
Percidae			
Yellow perch *Perca flavescens*	2		2

Table 7. Number of fish captured by species from 1996, 1998 - 2001 at Kletzsch Park station - Milwaukee River.

Family and species	YEAR					
	1996	1998	1999	2000	2001	Total
Esocidae						
Northern pike *Esox lucius*					1	1
Cyprinidae						
Central stoneroller *Campostoma anomalum*		43				43
Largescale stoneroller *Campostoma oligolepis*					6	6
Stoneroller spp. *Campostoma spp.*	39		8	7		54
Spotfin shiner *Cyprinella spiloptera*	2	24	4	22	23	75
Common carp *Cyprinus carpio*	2		6	2	1	11
Brassy minnow *Hybognathus hankinsoni*		2				2
Common shiner *Luxilus cornutus*	8	32	4	17	99	160
Hornyhead chub *Nocomis biguttatus*	1		1	6	8	16
Golden shiner *Notemigonus crysoleucas*		3				3
Emerald shiner *Notropis atherinoides*					2	2
Sand shiner *Notropis stramineus*	12	162	56	67	62	359
Bluntnose minnow *Pimephales notatus*	2	3	2	7	22	36
Catostomidae						
White sucker *Catostomus commersoni*		14	3	5	2	24
Redhorse spp. *Moxostoma spp.*	85					85
Silver redhorse *Moxostoma anisurum*				3	2	5
Golden redhorse *Moxostoma erythrurum*		42	13	56	41	152
Shorthead redhorse *Moxostoma macrolepidotum*			7	104	21	132
Greater redhorse *Moxostoma valenciennesi*		84	27	5	1	117
Ictaluridae						
Black bullhead *Ameiurus melas*	4		1			5
Yellow bullhead *Ameiurus natalis*			1		1	2
Stonecat *Noturus flavus*	3	13		1	2	19
Centrarchidae						
Rock bass *Ambloplites rupestris*	10	12	45	10	24	101
Green sunfish *Lepomis cyanellus*		4	3	1	2	10
Pumpkinseed *Lepomis gibbosus*			2	1	1	4
Bluegill *Lepomis macrochirus*				2		2
Smallmouth bass *Micropterus dolomieu*	4	77	93	67	47	288
Largemouth bass *Micropterus salmoides*			1	1	2	4
Black crappie *Pomoxis nigromaculatus*					1	1
Percidae						
Fantail darter *Etheostoma flabellare*		1				1
Logperch *Percina caprodes*	22	58	17	19	29	145
Walleye *Sander vitreus*		1	1			2

Table 8. Catch per unit effort (per 1000-m stretch) of fish captured by species from 1996, 1998-2001 at Kletzsch Park station - Milwaukee River.

Family and species	YEAR				
	1996	**1998**	**1999**	**2000**	**2001**
Esocidae					
Northern pike *Esox lucius*					2.2
Cyprinidae					
Central stoneroller *Campostoma anomalum*		245.7			
Largescale stoneroller *Campostoma oligolepis*					34.3
Stoneroller spp. *Campostoma spp.*	222.9		45.7	40	
Spotfin shiner *Cyprinella spiloptera*	11.4	137.1	22.9	125.7	131.4
Common carp *Cyprinus carpio*	11.4		34.3	11.4	5.7
Brassy minnow *Hybognathus hankinsoni*		11.4			
Common shiner *Luxilus cornutus*	45.7	182.9	22.9	97.1	565.7
Hornyhead chub *Nocomis biguttatus*	5.7		5.7	34.3	45.7
Golden shiner *Notemigonus crysoleucas*		17.1			
Emerald shiner *Notropis atherinoides*					11.4
Sand shiner *Notropis stramineus*	68.6	925.7	320	382.9	354.3
Bluntnose minnow *Pimephales notatus*	11.4	17.1	11.4	40	125.7
Catostomidae					
White sucker *Catostomus commersoni*		80	17.1	28.6	11.4
Redhorse spp. *Moxostoma spp.*	485.7				
Silver redhorse *Moxostoma anisurum*				17.1	11.4
Golden redhorse *Moxostoma erythrurum*		240	74.3	320	234.3
Shorthead redhorse *Moxostoma macrolepidotum*			40	594.3	120
Greater redhorse *Moxostoma valenciennesi*		480	154.3	28.6	5.7
Ictaluridae					
Black bullhead *Ameiurus melas*	8.7		2.2		
Yellow bullhead *Ameiurus natalis*			2.2		2.2
Stonecat *Noturus flavus*	6.5	28.3		2.2	4.3
Centrarchidae					
Rock bass *Ambloplites rupestris*	21.7	26.1	97.8	21.7	52.2
Green sunfish *Lepomis cyanellus*		8.7	6.5	2.2	4.3
Pumpkinseed *Lepomis gibbosus*			4.3	2.2	2.2
Bluegill *Lepomis macrochirus*				4.3	
Smallmouth bass *Micropterus dolomieu*	8.7	167.4	202.2	145.7	102.2
Largemouth bass *Micropterus salmoides*			2.2	2.2	4.3
Black crappie *Pomoxis nigromaculatus*					2.2
Percidae					
Fantail darter *Etheostoma flabellare*		5.7			
Logperch *Percina caprodes*	400	331.4	97.1	108.6	165.7
Walleye *Sander vitreus*		2.2	2.2		

Table 9. Number of fish captured by species at Brown Deer Road station, Milwaukee River.

Family and species	YEAR		
	1996	1998	Total
Esocidae			
Northern pike *Esox lucius*		2	2
Cyprinidae			
Spotfin shiner *Cyprinella spiloptera*		9	9
Common carp *Cyprinus carpio*	2	4	6
Golden shiner *Notemigonus crysoleucas*		1	1
Spottail shiner *Notropis hudsonius*		5	5
Sand shiner *Notropis stramineus*		73	73
Minnows & Carps unsp.		2	2
Catostomidae			
White sucker *Catostomus commersoni*		6	6
Redhorse spp. *Moxostoma spp.*	15		15
Golden redhorse *Moxostoma erythrurum*		28	28
Ictaluridae			
Stonecat *Noturus flavus*		2	2
Centrarchidae			
Rock bass *Ambloplites rupestris*	9	8	17
Green sunfish *Lepomis cyanellus*		49	49
Smallmouth bass *Micropterus dolomieu*	25	13	38
Largemouth bass *Micropterus salmoides*		8	8
Percidae			
Johnny darter *Etheostoma nigrum*		7	7
Logperch *Percina caprodes*	1	3	4

Table 10. Number of smallmouth bass, YOY and adult, (based on length frequency and age data), captured at Capitol Drive station from 1997 to 2001, Milwaukee River.

Year	No. of YOY	CPUE of YOY	No. of SMB age ≥ 1	CPUE of adult age ≥ 1
1997	60	32.4	6	3.2
1998	115	62.2	41	22.2
1999	61	33	195	105.4
2000	480	259.5	174	94.1
2001	189	102.2	92	49.7

Table 11. Length (total, mm) at age of smallmouth bass captured at Capitol Drive station from 1998 to 2001, Milwaukee River.

Age	1998	1999	2000	2001
0	118 (20)	97 (23)	No data	77 (46)
1	173 (23)	161 (59)	166 (12)	145 (3)
2	241 (9)	188 (11)	222 (65)	222 (2)
3	299 (4)	263 (5)	283 (15)	None
4	325 (5)	300 (1)	335 (9)	None
5	None	355 (1)	None	355 (2)

Numbers in parenthesis represent number of fish.

Table 12. Length (total, mm) at age of smallmouth bass, by year-class, captured at Capitol Drive station, Milwaukee River.

Year-class	Age		
	0	1	2
1998	118 (20)	161(59)	222 (65)
1999	97 (23)	166 (12)	222 (2)
2000	No data	145 (3)	
2001	77 (46)		

Numbers in parenthesis represent number of fish.

Table 13. Length (total, mm) at age of smallmouth bass captured at Kletzsch Park station from 1996, 1998-2001, Milwaukee River.

Age	1996	1998	1999	2000	2001
0	-	73 (3)	-	-	59 (2)
1	1	152 (12)	143 (45)	161 (5)	154 (9)
2	1	214 (2)	199 (5)	194 (33)	247 (1)
3	-	313 (1)	-	-	234 (2)
4	-	319 (1)	335 (1)	-	-
5	-	-	-	-	-
6	-	411 (1)	-	-	-
7	1	-	-	-	-

Note: Number in the parenthesis represents number of smallmouth bass. No length data taken in 1996. No sample was taken in 1997.

Table 14. Number of walleye fingerlings stocked in the lower Milwaukee River below the former North Avenue Dam as part of the walleye restoration program.

Year	# stocked	Age at stocking	Source	Strain	Mark type
1995	7,626	Extended growth fingerlings[1]	WDNR Spooner Hatchery	Unknown	RP/REL
1996	9,972	Extended growth fingerlings[1]	WDNR Spooner Hatchery	Unknown	LP/GEL
1997	None				
1998	3,155	Extended growth fingerlings[1]	Private Hatchery	Lake Michigan	RV/BEL
1999	7,700	Fingerlings[2]	WDNR Kettle Moraine Springs Hatchery	Lake Michigan	None
2000	9,880	Extended growth fingerlings[1]	WDNR Spooner Hatchery	Lake Michigan	LV/OEL
2001	10,000	Extended growth fingerlings[1]	WDNR Spooner Hatchery	Lake Michigan	RP/PEL
2002	5,600	Extended growth fingerlings[1]	WDNR Spooner Hatchery	Lake Michigan	LP
2003	11,000	Extended growth fingerlings[1]	WDNR Spooner Hatchery	Lake Michigan	RV
2004	1,924	Extended growth fingerlings[1]	WDNR Lake Mills Hatchery	Lake Michigan	RP

[1] Extended growth fingerlings (average size 150-180mm total length)
[2] Fingerlings (average size 64mm total length)

Legend:

RP = right pectoral fin clip
LP = left pectoral fin clip
RV = right ventral fin clip
LV = left ventral fin clip

REL = red elastomer
GEL = green elastomer
BEL = blue elastomer
OEL = orange elastomer
PEL = purple elastomer

Table 15. Population estimate of walleye (all sizes combined) in the lower Milwaukee River – 1996, 1998, 2002-2005.

Assessment year	Estimated walleye	95% confidence interval	Method (Ricker 1975)	Comment
1996	795	115≤ N ≤ 1475	Chapman Modification of a Petersen method	No adult fish
1998	745	405≤ N ≤ 1586	Schnabel multiple capture	All walleye
2002	428	129 ≤ N ≤ 727	Chapman Modification of a Petersen method	All walleye
2003	875	401≤ N ≤ 2388	Schnabel multiple capture	All walleye
2004	5,336	2,979≤N≤10,809	Schnabel multiple capture	All walleye
2005	506	256≤N≤1,190	Schnabel multiple capture	All walleye

Table 16. Total directed angling effort (hours) for walleye from March 15 through October 31, 1990 to 2004 in the lower Milwaukee River, Menomonee River canals and the harbor.

Creel survey year	Fishery type					
	Ramp	Pier	Shore	Stream		
				Downstream of the Dam	Upstream of the Dam	Menomonee River /canals
1990	0	0	696	0	0	NA
1991	0	0	167	0	0	NA
1992	0	0	13	0	0	NA
1993	0	0	13	0	0	NA
1994	0	122	23	0	116	NA
1995	0	0	0	0	0	NA
1996	0	0	148	0	0	NA
1997	0	18	734	1606	221	NA
1998	871	0	3,551	0	0	NA
1999	0	34	360	0	0	NA
2000	0	0	242	0	222	NA
2001	0	0	67	0	0	109
2002	0	328	632	285	175	2,652
2003	133	614	1,751	79	665	4,271
2004	262	0	1,048	144	2,645	883

Table 17. Lake sturgeon stocking in Milwaukee and Manitowoc Rivers - 2003-05.

Year	Milwaukee River			Manitowoc River		
	Fingerlings[1]	Yearlings[1]	Juveniles/ adults[1]	Fingerlings[2]	Yearlings[2]	Juveniles/ adults[2]
2003	0	0	8	0	0	0
2004	2,000 WR	200 WR	6	0	0	0
2005	1000 WR	100 WR	6	1000 WR	100 WR	0

[1] Milwaukee River Lake Sturgeon marked with a right ventral finclip. Up to 25% of fingerlings will be PIT tagged. Up to 10 fingerlings, yearlings and juvenile/adults will be radio tagged.
[2] Manitowoc River Lake Sturgeon marked with a left ventral finclip.
WR = Wolf River Strain Lake Sturgeon

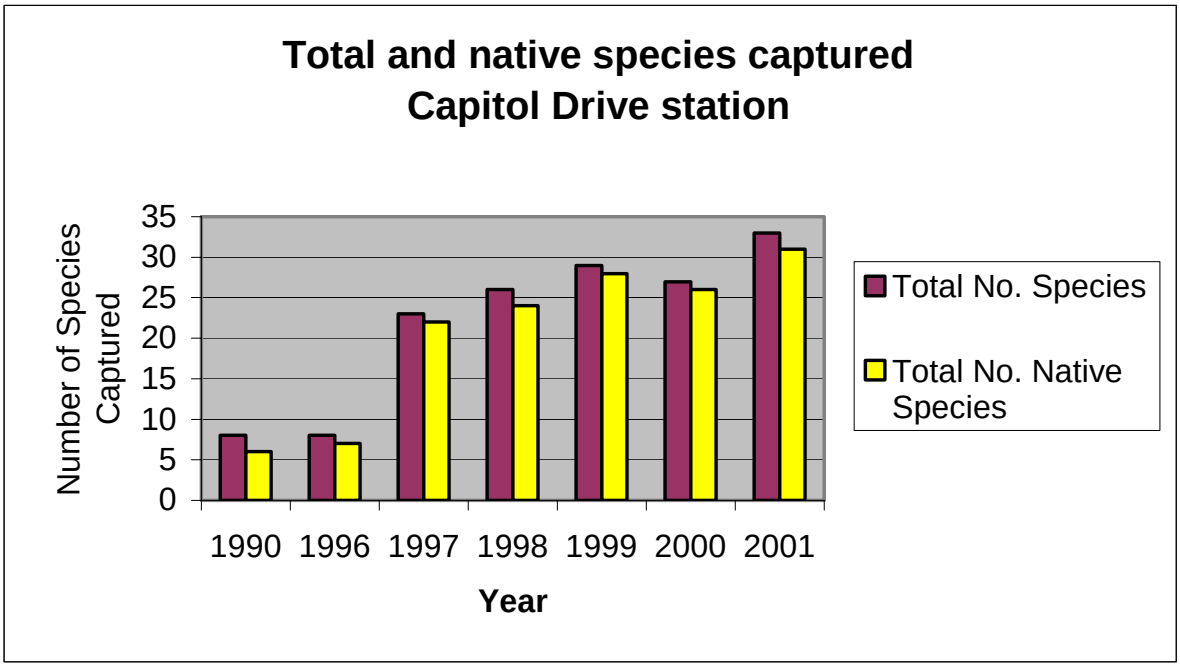


Figure 9a. Total number of native fish species in relation to total species captured at the Capitol Drive station, Milwaukee River, 1990, 1996-2001.

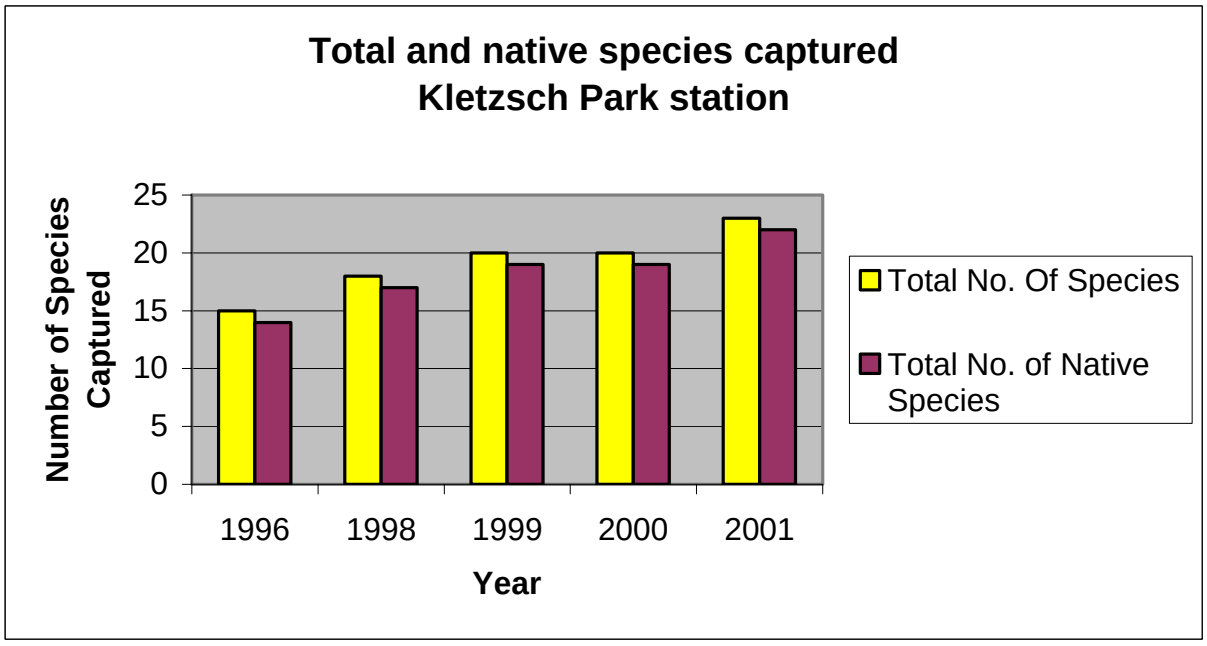


Figure 9b. Total number of native species in relation to total species captured at the Kletzsch Park station, Milwaukee River, 1996, 1998-2001.

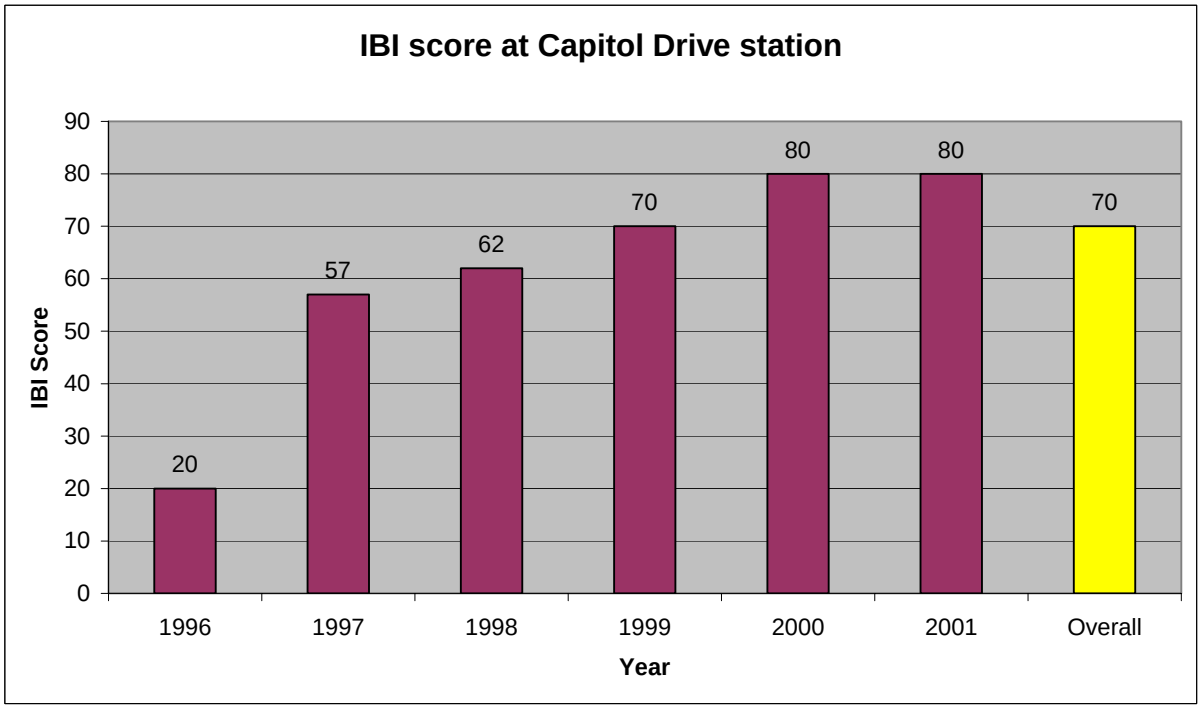


Figure 10a. IBI scores at the Capitol drive station from 1996 (pre-drawdown), 1997-2001 (post-drawdown). Overall refers to combined data from 1997 to 2001.

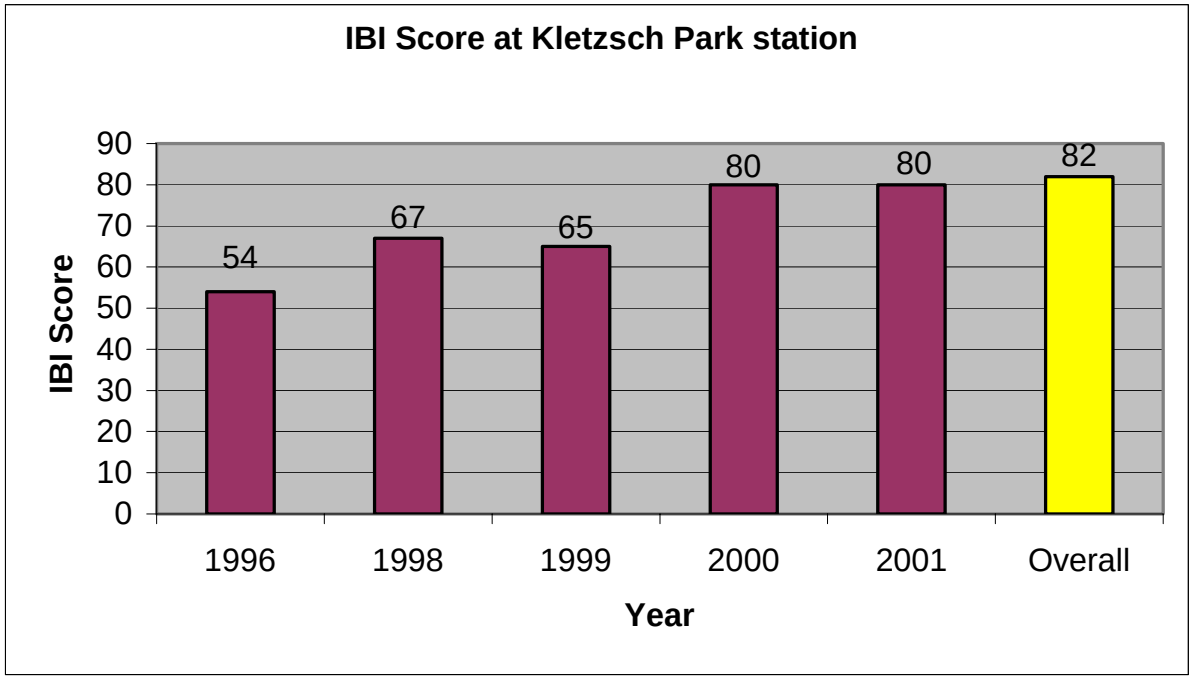


Figure 10b. IBI scores at the Kletzsch Park station from 1996, 1998-2001. Overall refers to combined data from 1996, 1998-2001.

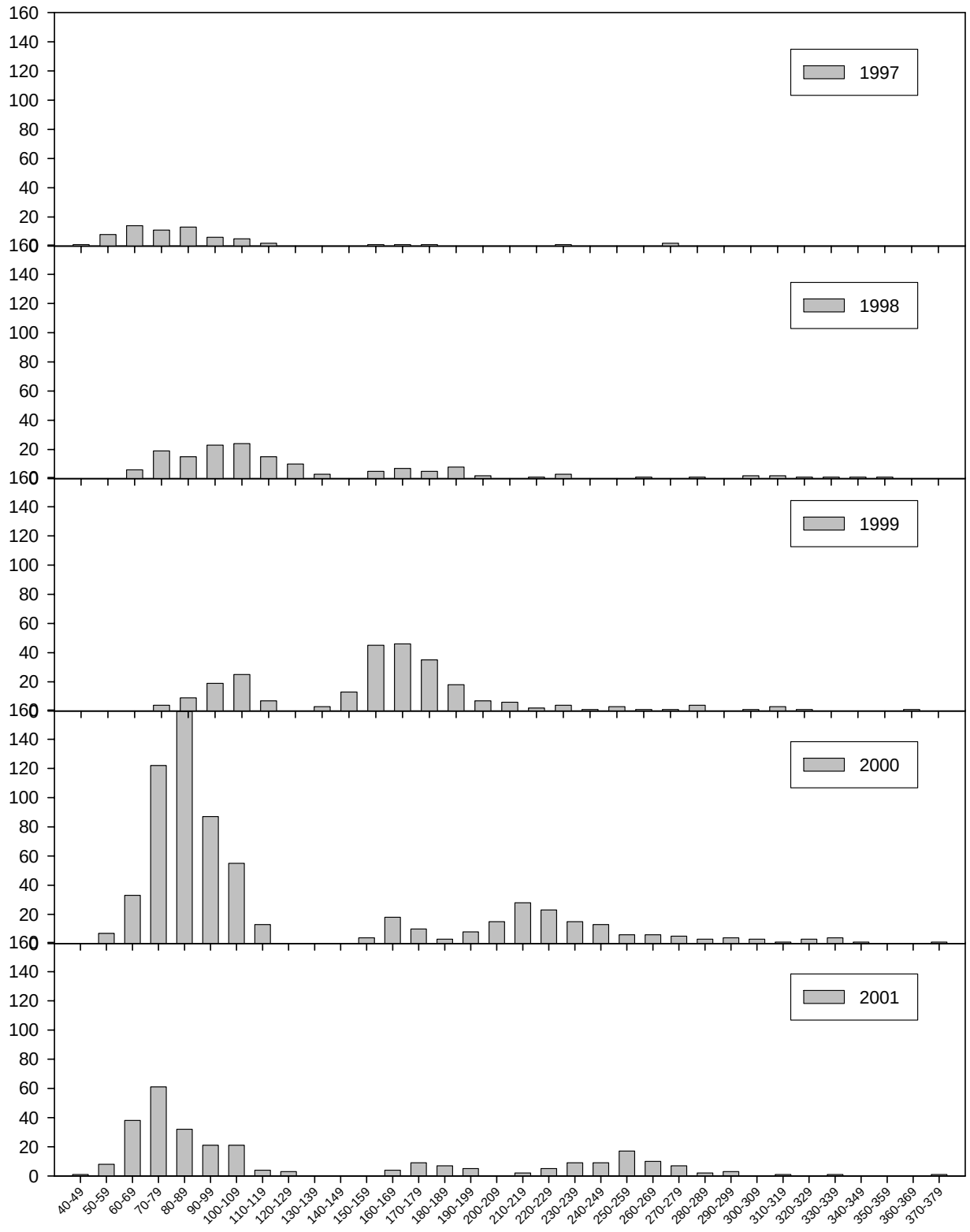
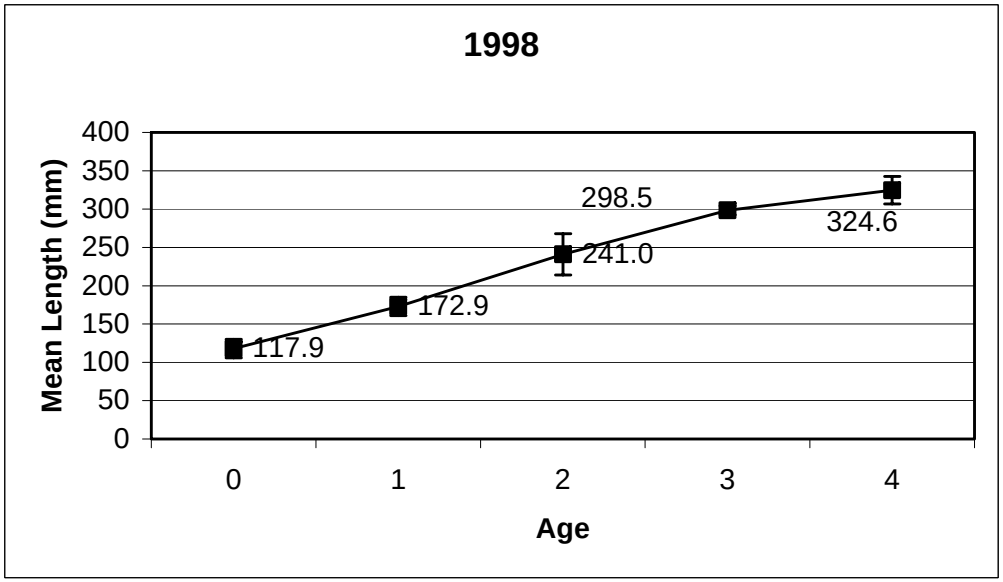
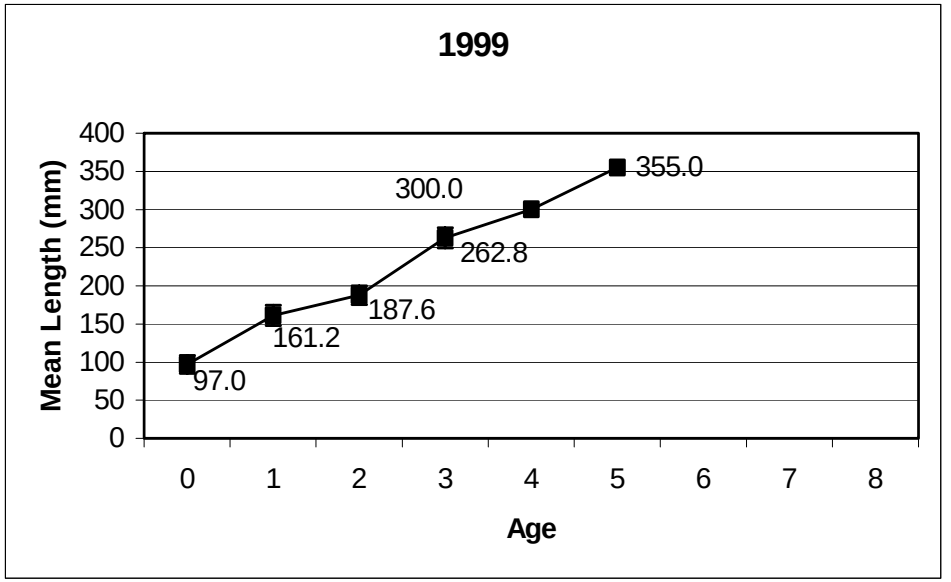
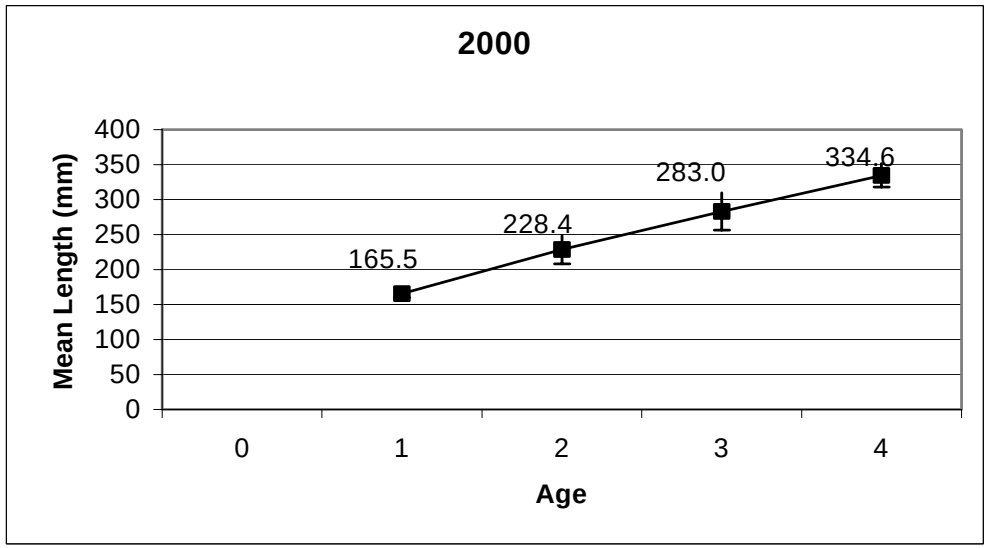


Figure 11. Size distribution of smallmouth bass – Capitol Drive station (Y - axis = Number of fish, X - axis = Length intervals in mm).







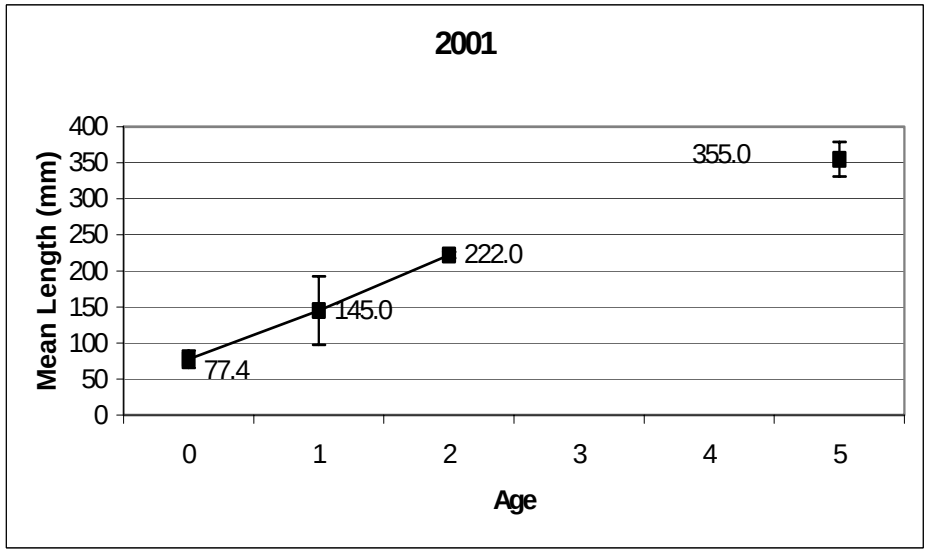


Figure 12. Mean length (mm, total length) at age of smallmouth bass from Capitol Drive station, 1998 – 2001.

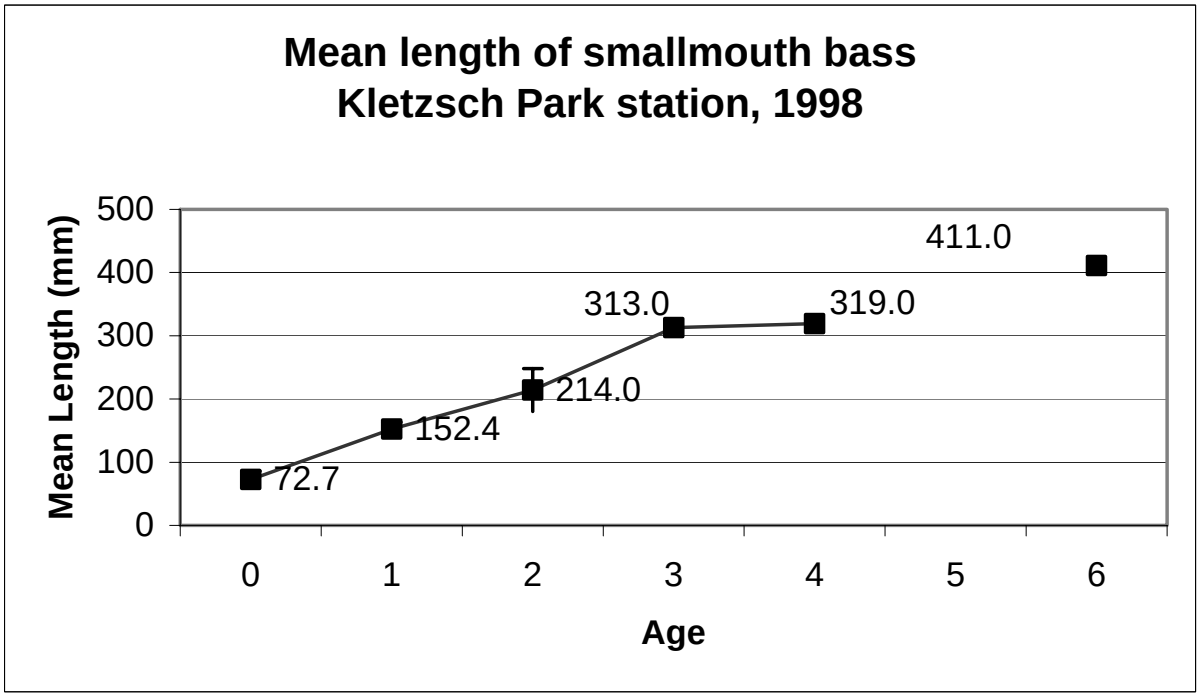


Figure 13. Mean length (mm, total length) at age of smallmouth bass from Kletzsch Park station, 1998.

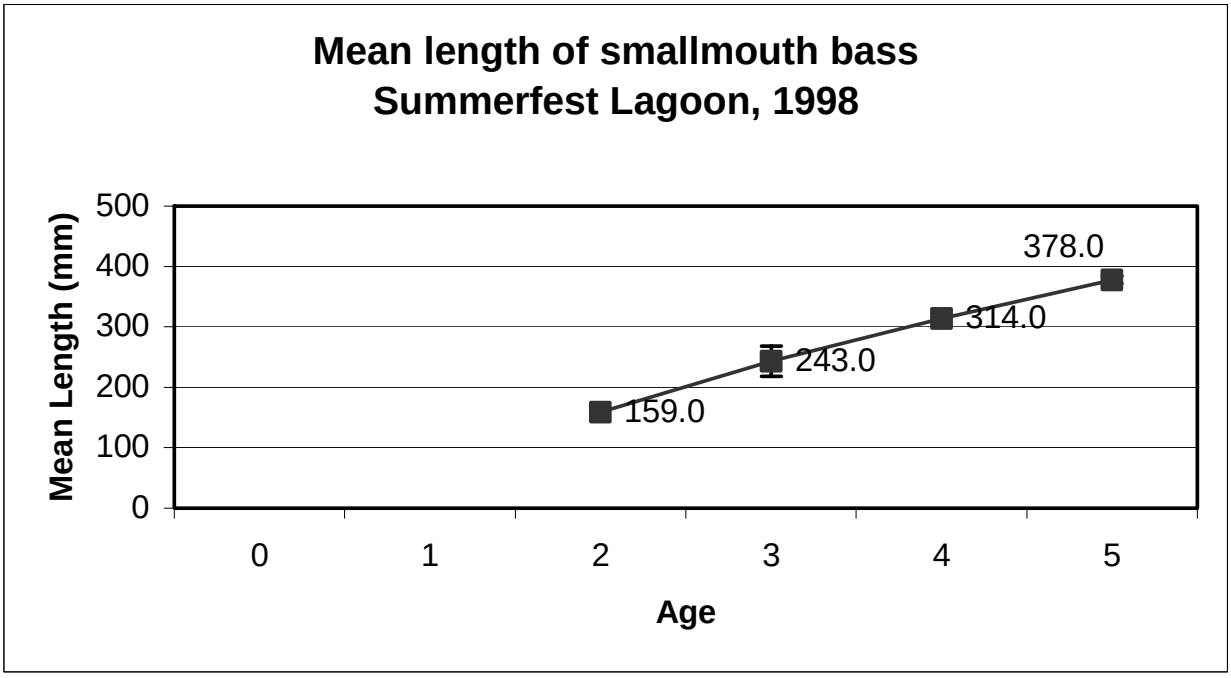


Figure 14. Mean length (mm, total length) at age of smallmouth bass from Summerfest Lagoon, 1998.

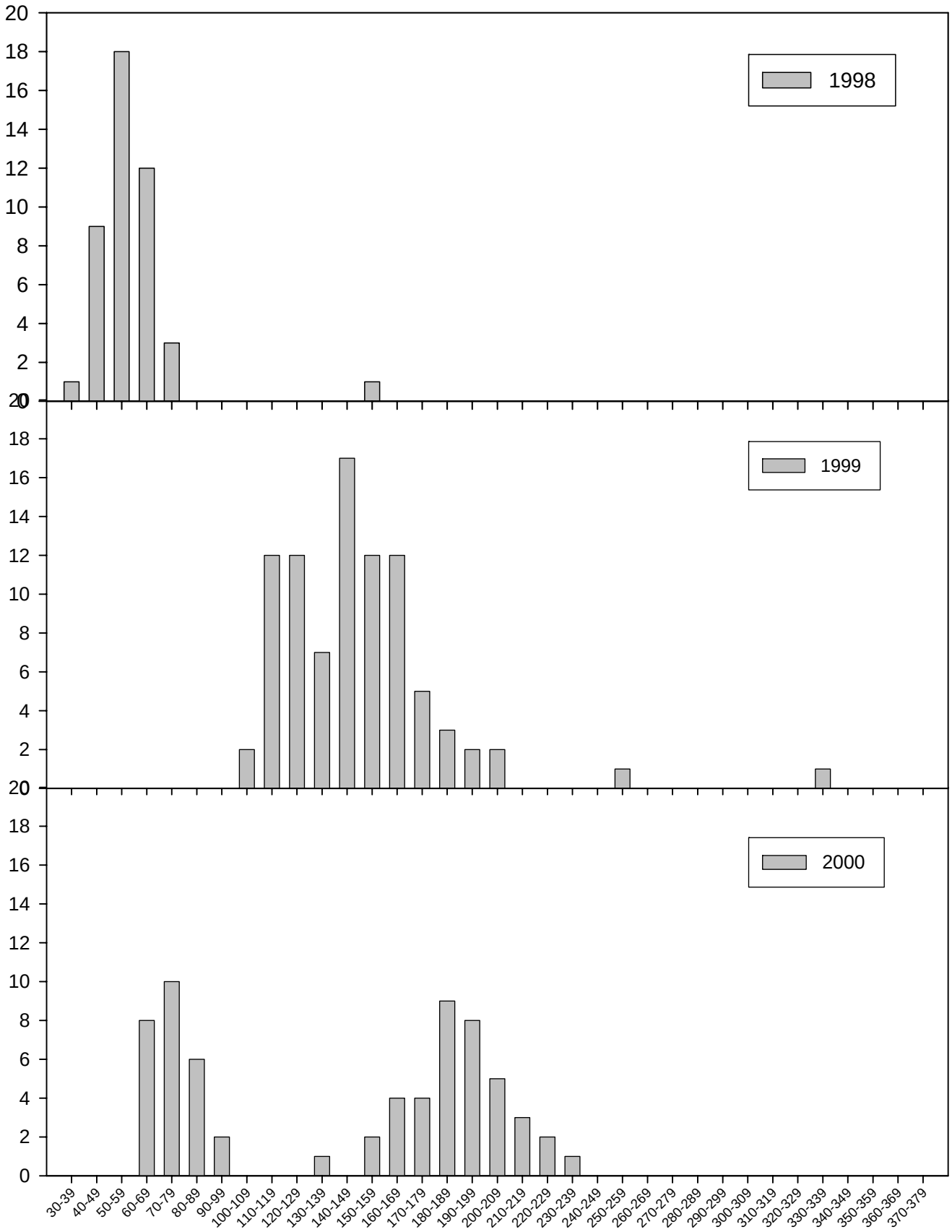


Figure 15. Size distribution of smallmouth bass – Kletzsch Park station (Y - axis = Number of fish, X - axis = Length intervals in mm)

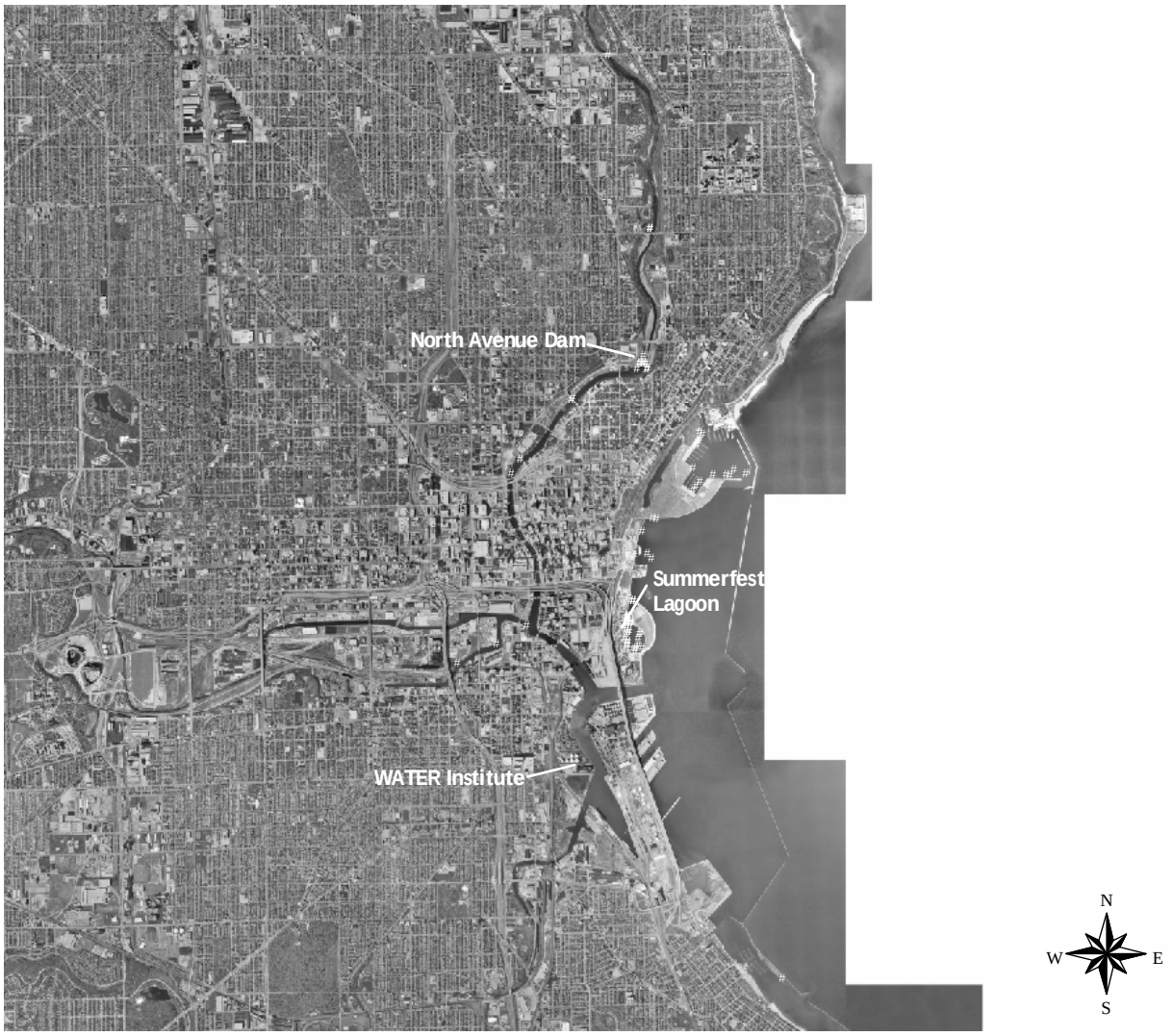


Figure 16. Movement and dispersal of radio-tagged smallmouth bass in the Lower Milwaukee River and Harbor, 2000-2002. (White dots represent individual fish found on the day of tracking)

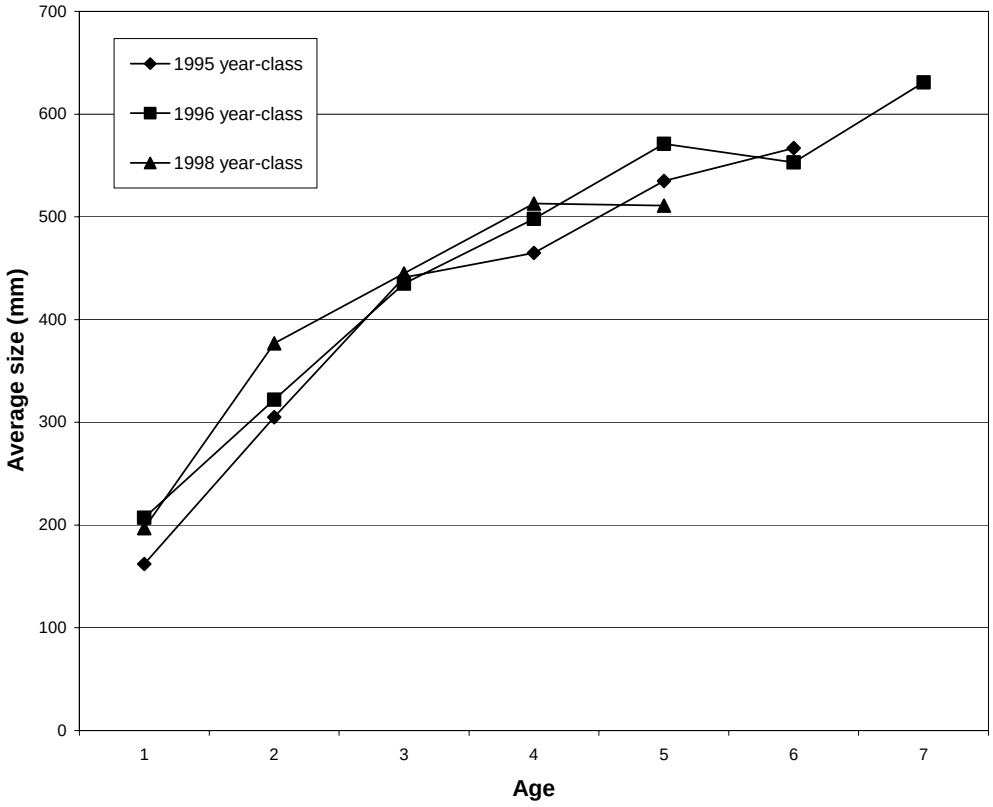


Figure 17. Growth pattern in three different year-classes of walleye stocked in the lower Milwaukee River.

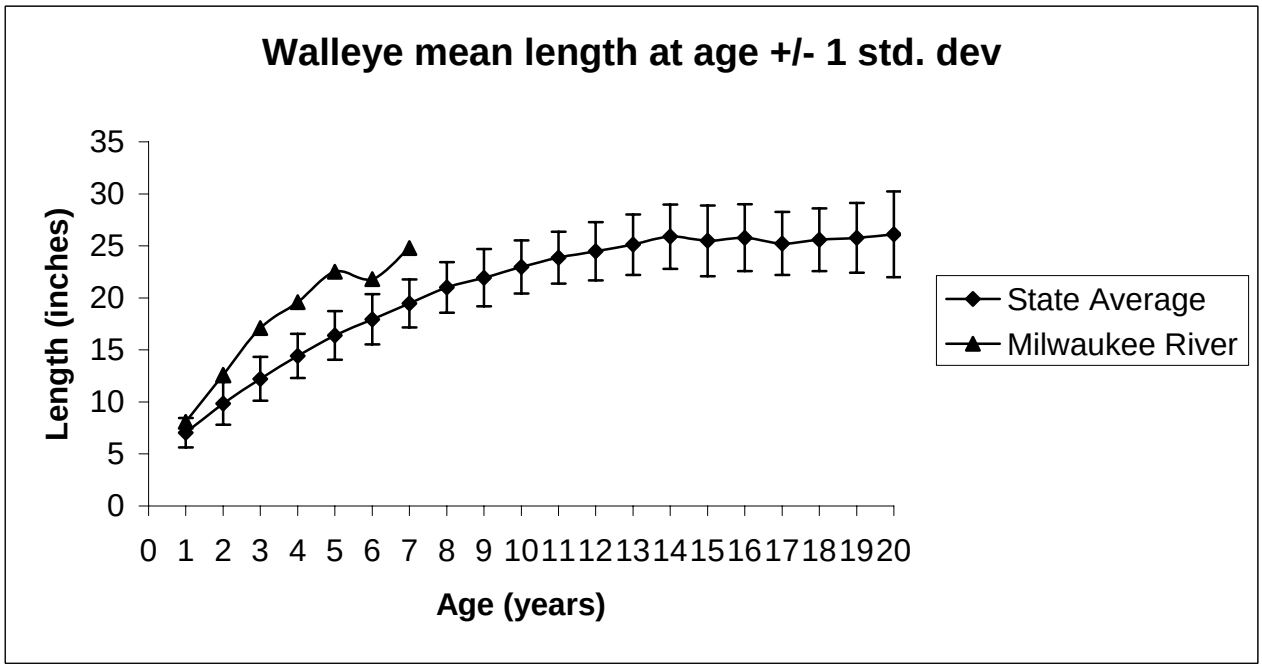


Figure 18. Comparison of average size at age of walleye from Milwaukee Harbor and other statewide populations.

Appendix 1

Milwaukee River/Harbor Comprehensive Survey Sampling Sites, 1996-2001.

Location	Station	Code	Years/Dates sampled	Gear Type	Latitude/Longitude
Kinnickinnic River	Chase Avenue to 1st Street	KKR1	1997	Boomshocker	43.9974262 -87.9120603
Kinnickinnic River	Lincoln Avenue to Becher Street	KKR2	1997	Boomshocker	43.0029743 -87.9120951
McKinley Marina	McKinley north slips	MCKNS	1997	Boomshocker	43.0506209 -87.8848106
McKinley Marina	McKinley north rubble wall	MCKRN	1997,2000	Boomshocker	43.0501504 -87.8821652
McKinley Marina	McKinley Pier riprap	MCKPR	1997	Boomshocker	43.0467974 -87.8798747
Menomonee River	16th Street to 26th Street	MNR1	1997	Boomshocker	43.0314805 -87.9471835
Menomonee River	6th Street to I-94	MNR2	1997	Boomshocker	43.0320606 -87.9225574
Menomonee River	Miller Park (35th Street upstream to I-94)	MNR3	1999	Streamshocker	43.0248088 -87.9583741
Menomonee River	Menomonee River Canals	MNRCNL	2000	Boomshocker	43.0326250 -87.9150761
Milwaukee River	Upstream of Thiensville Dam (1.3 miles of impoundment)	MRATD	1996	Boomshocker	43.2340571 -87.9571798
Milwaukee River	Brown Deer Road (0.25 miles downstream from bridge)	MRBD	1996,1998	Mini-Boom/ Streamshocker	43.1755369 -87.9588626
Milwaukee River	Downstream of Highway 60 Dam (1000 ft. downstream from Dam)	MRBH60	1996	Streamshocker	43.3163062 -87.9488111
Milwaukee River	Capitol Drive (Chambers Street upstream to Capitol Drive)	MRBS	1997-2001	Streamshocker	43.0739795 -87.8925781
Milwaukee River	Downstream of Thiensville Dam (from Dam to confluence of Pigeon Creek)	MRBTD	1996	Boomshocker	43.2307410 -87.9796086
Milwaukee River	Estabrook Impoundment (Bender Road downstream to Dam)	MREI	2000-2001	Mini boomshocker	43.1295245 -87.9260150
Milwaukee River	Kletzsch Park (Bender Road upstream to Kletzsch Park Dam)	MRKP	1996,1998-2001	Streamshocker	43.1298376 -87.9263911
Milwaukee River	Kern Park (Kern Park to Capitol Drive)	MRKRN	1996	Streamshocker	43.0788941 -87.8929826
Milwaukee River	Lime Kiln Park (from Dam 0.25 mile downstream)	MRLKP	1996	Streamshocker	43.3029073 -87.9568433
Milwaukee River	North Avenue Dam (Pleasant Street to former Dam)	MRNA	1996-1997,1999-2001	Boomshocker	43.0577391 -87.8946692
Milwaukee River	Chambers Street (Chambers Street downstream to N. Ave bridge)	MRUNA	2001	Mini boomshocker	43.0603650 -87.8936701
Summerfest Lagoon	Island outer rockwall	OSFLG	2000	Boomshocker	43.0341511 -87.8960724
Summerfest Lagoon	Lagoon (inside)	SFLG	1997-2000	Boomshocker	43.0318613 -87.8952564
Milwaukee Harbor	Art Museum breakwall	MHAM	2000	Boomshocker	43.0379043 -87.8963584
Milwaukee Harbor	Jones Island Confined Disposal Facility Breakwall	JICDF	1997	Boomshocker	43.0067187 -87.8861206
Milwaukee Harbor	Inside South Shore Rubble Wall	ISSRW	1997	Boomshocker	42.9935363 -87.8745947
Milwaukee Harbor	South Shore Marina moorings	SSM	1997	Boomshocker	42.9911585 -87.8756265
Milwaukee Harbor	South Shore Marina riprap	SSRR	1997	Boomshocker	42.9960957 -87.8777880
Milwaukee Harbor	Texas Rock Jetties	TRJ	1997	Boomshocker	42.9889209 -87.8723474

Appendix 2

Number of fish captured by species from the Kinnickinnic River in 1997.

Family and species	Site		
	KKR1	KKR2	Total
Clupeidae			
Alewife *Alosa pseudoharengus*	7	17	24
Gizzard shad *Dorosoma cepedianum*	15	71	86
Cyprinidae			
Goldfish *Carassius auratus*	1		1
Common carp *Cyprinus carpio*	11	8	19
Common carp x Goldfish	8	1	9
Golden shiner *Notemigonus crysoleucas*		2	2
Fathead minnow *Pimephales promelas*	1	2	3
Catostomidae			
White sucker *Catostomus commersoni*	16	8	24
Redhorse spp. *Moxostoma spp*	1		1
Greater redhorse *Moxostoma valenciennesi*	1		1
Ictaluridae			
Black bullhead *Ameiurus melas*		1	1
Gasterosteidae			
Threespine stickleback *Gasterosteus aculeatus*		2	2
Centrarchidae			
Pumpkinseed *Lepomis gibbosus*		1	1

(see Appendix 1 for site codes)

KKR1 = Chase Avenue to 1st Street

KKR2 = Lincoln Avenue to Becher Street

Appendix 3

Number of fish caught by species from the Milwaukee Harbor sites in 1997.

Family and species	Site					
	ISSRW	JICDF	MCKNS	SSM	SSRR	TRJ
Clupeidae						
Alewife *Alosa pseudoharengus*			49		33	
Gizzard shad *Dorosoma cepedianum*			1		19	
Salmonidae						
Rainbow trout *Oncorhynchus mykiss*					1	
Chinook salmon *Oncorhynchus tshawytscha*					1	
Brown trout *Salmo trutta*	1					
Lake trout *Salvelinus namaycush namaycush*			1			
Esocidae						
Northern pike *Esox lucius*			1		1	
Cyprinidae						
Common carp *Cyprinus carpio*			1			1
Catostomidae						
Sucker spp.					1	
White sucker *Catostomus commersoni*	1	2	19	6	19	
Redhorse spp. *Moxostoma spp.*			1		1	
Golden redhorse *Moxostoma erythrurum*	3		8			1
Greater redhorse *Moxostoma valenciennesi*	2	3	2		4	
Ictaluridae						
Black bullhead *Ameiurus melas*						
Gasterosteidae						
Threespine stickleback *Gasterosteus aculeatus*			1		1	
Centrarchidae						
Rock bass *Ambloplites rupestris*						
Green sunfish *Lepomis cyanellus*						
Pumpkinseed *Lepomis gibbosus*			2			
Bluegill *Lepomis macrochirus*						
Smallmouth bass *Micropterus dolomieu*			2			
Largemouth bass *Micropterus salmoides*			4			
Black crappie *Pomoxis nigromaculatus*			9			
Percidae						
Walleye *Sander vitreus*						
Cottidae						
Sculpin spp.	1					

(See Appendix 1 for site codes)
ISSRW = Inside South Shore Rubble Wall
JICDF = Jones Island Confined Disposal Facility Breakwall
MCKNS = McKinley north slips
SSM = South Shore Marina moorings
SSRR = South Shore Marina riprap
TRJ = Texas Rock Jetties

Milwaukee River at North Avenue Dam, ca. 1910

North Avenue Dam, August 2005. Photo: WDNR

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