

Revisiting the Minnesota River Assessment Project

An Evaluation of Fish and Invertebrate Community Progress



Minnesota Pollution Control Agency

May 2011

Legislative Charge

The Minnesota Pollution Control Agency is to spend \$348,000 to retest the comprehensive assessment of the biological conditions of the lower Minnesota River and its tributaries within the Lower Minnesota River Major Watershed, as previously assessed from 1976 to 1992 under the Minnesota River Assessment Project (MRAP). The assessment must include the same fish species sampling at the same 116 locations and the same macroinvertebrate sampling at the same 41 locations as the MRAP assessment. The assessment must: (1) include an analysis of the findings; and (2) identify factors that limit aquatic life in the Minnesota River. HF 1231, Article 2, Section 4(a)

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Minnesota Pollution Control Agency

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Forward

Residing in the southwestern portion of Minnesota, the Minnesota River Basin encompasses parts or all of 38 counties and contains 13 major watersheds, which drain nearly 20 percent of Minnesota (Figure 1) (Musser et al. 2009). The Minnesota River originates at Big Stone Lake (South Dakota) where it flows southeast to Mankato and abruptly turns to the northeast before joining with the Mississippi River near Fort Snelling, Minnesota. At 335 miles long, the Minnesota River and its accompanying watersheds drain approximately 16,770 square miles (approximately 10 million acres) (Musser et al. 2009).

Historically, the Minnesota River Basin was dominated by native prairie grassland (~78 percent, 18 million acres); however, today less than 200,000 acres exist in the region primarily due to the conversion of prairies for agricultural production (Musser et al. 2009). Currently, agriculture dominates the landscape where greater than 78 percent of the surrounding landuse is agriculture while the other 22 percent is made up of urban, forest, and grassland areas (Figure 1). Furthermore, the Minnesota River Basin was historically scattered with prairie wetlands, due to the advent of hydrologic modifications (i.e. tile drainage) nearly 90 percent of these wetlands have disappeared, and are now home to a majority of Minnesota's largest corn and soybean farms (Musser et al. 2009). While several improvements to the landscape have been made since the original Minnesota River Assessment Project (MRAP) (i.e. implementation of conservation easements and best management practices), several environmental issues persist within the Minnesota River Basin (Feist 2002 and Musser et al. 2009).

Human influence throughout much of the Minnesota River Basin has come in many forms: chemical pollutants from municipal and industrial point source discharges, agricultural runoff of sediment, nutrients and pesticides, hydrologic alteration from stream channelization, dams and artificial drainage, and habitat alteration from agricultural, urban, and residential encroachment (Feist 2002; Musser et al. 2009).

In 1992, Minnesota Governor Arne Carlson declared the Minnesota River "needs tremendous improvement," so he issued a challenge to make the river fishable and swimmable by 2002. In response to this declaration, a cleanup program was launched to meet this goal. Since Carlson's remark, groups and programs such as the Minnesota River Citizen Advisory Committee (1992), the Minnesota River Joint Powers Board (1995), and the Conservation Reserve Enhancement Program (CREP) (1998) were formed (Minnesota River Basin Data Center 2011).

Beginning in 1989 and continuing through 1993, MRAP was designed to assess the condition of the Minnesota River Basin and to provide more definitive information regarding impairment of fish and macroinvertebrate communities throughout the basin. The project created a widespread monitoring network within the basin, which was led by the Minnesota Pollution Control Agency (MPCA) with assistance from federal, state, and local government agencies, as well as university involvement (Bailey et al. 1993, Zischke et al. 1994).

Based on the results of the previous studies, biological communities were determined to be severely to moderately impaired (Bailey et al. 1993, Zischke et al. 1994). For fish communities, the degraded conditions were attributed to lack of instream habitat and cover, which was a result of stream channelization and excess sedimentation (Bailey et al. 1993). Invertebrate communities were determined to be degraded throughout much of the basin; however no explanation for the status of communities was provided as this was a baseline effort (Zischke et al. 1994).

In 2009-2010, the biological portion of this project was replicated to determine the current biological conditions of the Minnesota River Basin and measure the success of restoration efforts. In addition, sites sampled in 2001 as part of a MRAP progress evaluation by the MPCA were replicated using current methods and protocols. This project was led by the South Biological Monitoring Unit of the MPCA with funding provided by the Minnesota Legislature.

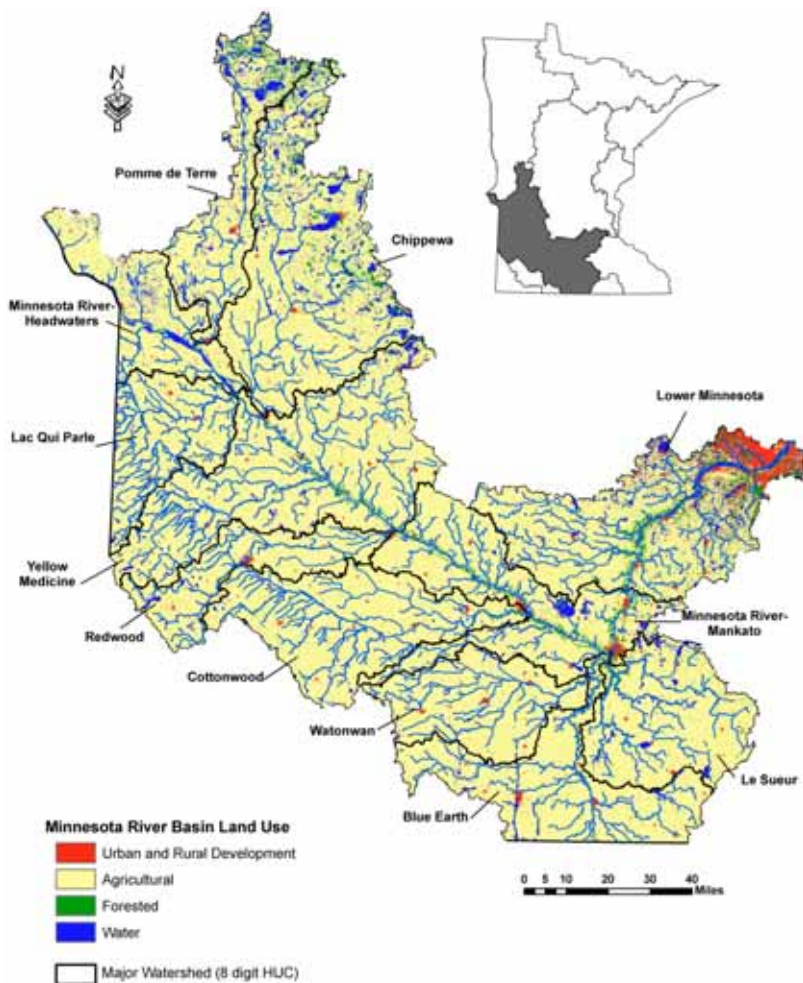
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Purpose of Study

The objective of the present study was to provide an update on the condition of fish and benthic macroinvertebrate communities within the Minnesota River Basin since the previous studies (Bailey et al. 1993 and Zischke et al. 1994). To allow for appropriate temporal comparisons, the experimental designs of the previous studies were replicated. In addition to the original sample periods, fish samples were collected between 2001 and 2010 using current MPCA methods. Several of the same sites were sampled during this survey with a few new sites added. These samples were included in this analysis to provide a current perspective on biological conditions.

Figure 1: Map depicting the major watersheds and current land use within the Minnesota River Basin.



Study Sites and Site Selection

Sites for this study were located at or near the same locations of the first project in the early 1990s (Figure 2). A wide variety of characteristics for site selection were considered in the previous studies including: areas with extensive vegetative buffer, natural morphology, differing stream sizes, diversity of available habitats, and land uses; among others.

One hundred fourteen of the 117 original sites were re-sampled to assess the fish community condition (Figure 2) and another 33 of the original 41 sites were re-sampled to determine benthic macroinvertebrate conditions (Figure 3). In addition, 30 of 31 sites sampled in 2001 as part of a MRAP progress evaluation were re-sampled for fish community and 15 of those 31 sites were sampled for benthic macroinvertebrates.

Methods

Fish sampling

To allow for a comparison between the original MRAP survey and this new survey, we attempted to duplicate the fish sampling methods. Sampling took place during July-August in 2009 and June-September in 2010 during daylight hours in normal-low flow conditions.

Electrofishing was the sole method used for collecting fish. Using an adjustable, square wave, pulsed direct current (DC), crews were able to effectively capture fish in a safe and efficient manner from all available habitat types. Four different gear types were used and chosen according to the depth and width of the stream (backpack shocker, stream shocker, mini-boom shocker, and boom shocker). Due to issues such as accessibility, changes in stream size, and availability of equipment, some sites were not sampled with the same gear chosen during the first visit. However, the distance fished, and time fished remained relatively the same in the two projects.

All fish captured were identified to species and counted. For each species, the minimum and maximum lengths were recorded in millimeters. The total wet weight of each species was also recorded to the nearest 0.5 gram. Each fish was also examined for external anomalies. Voucher specimens were collected for each species at sites where a fish's identity was questionable. Large specimens where taxonomic identification was common knowledge were not kept. Voucher specimens were preserved and sent to the Minnesota Bell Museum of Natural History for verification.

For the subset of 31 sites that were sampled in both 2001 and 2010, the current MPCA fish and invert sampling protocols were used (Brasuhn 2009).

Fish communities were evaluated using an index of biological integrity (IBI) that was initially developed during MRAP and was subsequently revised to include all warmwater streams in Minnesota. The IBI provides a numerical score to describe how the biological community, in this case the fish community, has changed from a reference or least impacted condition (Bailey et al. 1993).

Benthic macroinvertebrate collection methods

To allow for direct comparison with the original study, benthic macroinvertebrate collection methods were based on methods in Zischke et al. (1994). Six Hester-Dendy samplers were placed in the same approximate location at 33 of the 41 original MRAP locations (Figure 3). It should be noted that not all original locations were revisited due to a myriad of reasons: vandalism (removal of sampling apparatus from the site), dry streambeds, and inappropriate habitat type. Hester-Dendy samplers were allowed to colonize for six weeks prior to retrieval. Upon retrieval Hester-Dendy samples were preserved in ~85 percent ethanol and shipped to Rithron Inc. (Missoula, Montana USA) for processing and benthic macroinvertebrate identification. To maintain consistency with current MPCA benthic macroinvertebrate sampling protocols and the original study, Hester-Dendy samplers were deployed in August and collected in September. It is important to note that in the original MRAP study, Hester-Dendy samplers were deployed from June through August and benthic macroinvertebrate collections were made from July through October. However, the start date of the current project did not allow for the collection of benthic macroinvertebrates during the early summer months.

Therefore, the present analysis was constrained to samples collected during the months of September and early October for temporal consistency. Benthic macroinvertebrate communities' change as a result of temperature and daylight periods, and therefore, samples collected during the summer months (June, July, and August) may not provide consistent comparisons with the present study. Furthermore, the MPCA has established index periods for collecting benthic macroinvertebrates based upon known life history characteristics for many of the species that occur within Minnesota (Chirhart 2004).

Between 2001 and 2010 the MPCA sampled benthic macroinvertebrates from 15 locations within the Minnesota River Basin using a qualitative multi-habitat approach that is currently used by MPCA to conduct benthic macroinvertebrate surveys. This methodology utilizes D-frame dip-nets (500 μm mesh) to collect composite benthic macroinvertebrate samples from dominant habitats observed within a given reach. These data were used to generate a benthic macroinvertebrate IBI score. These data provide an additional comparison similar to that of the original MRAP study using the current MPCA sampling protocols for benthic macroinvertebrates.

Figure 2: Map depicting the original Minnesota River Assessment Project (MRAP) fish sampling locations within the Minnesota River Basin.

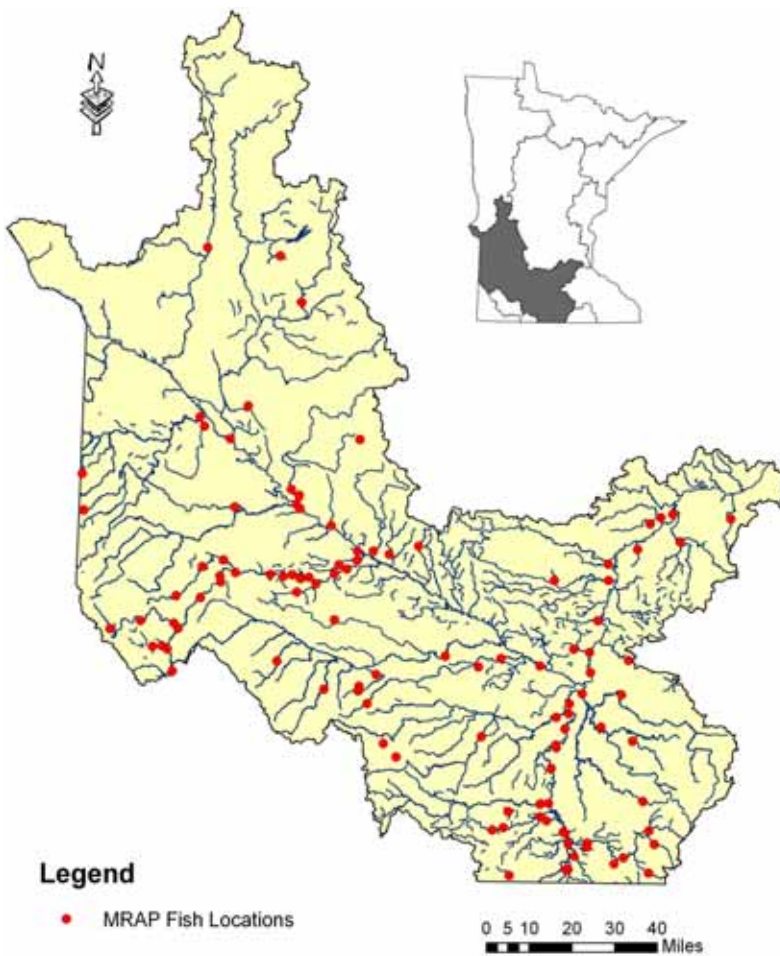
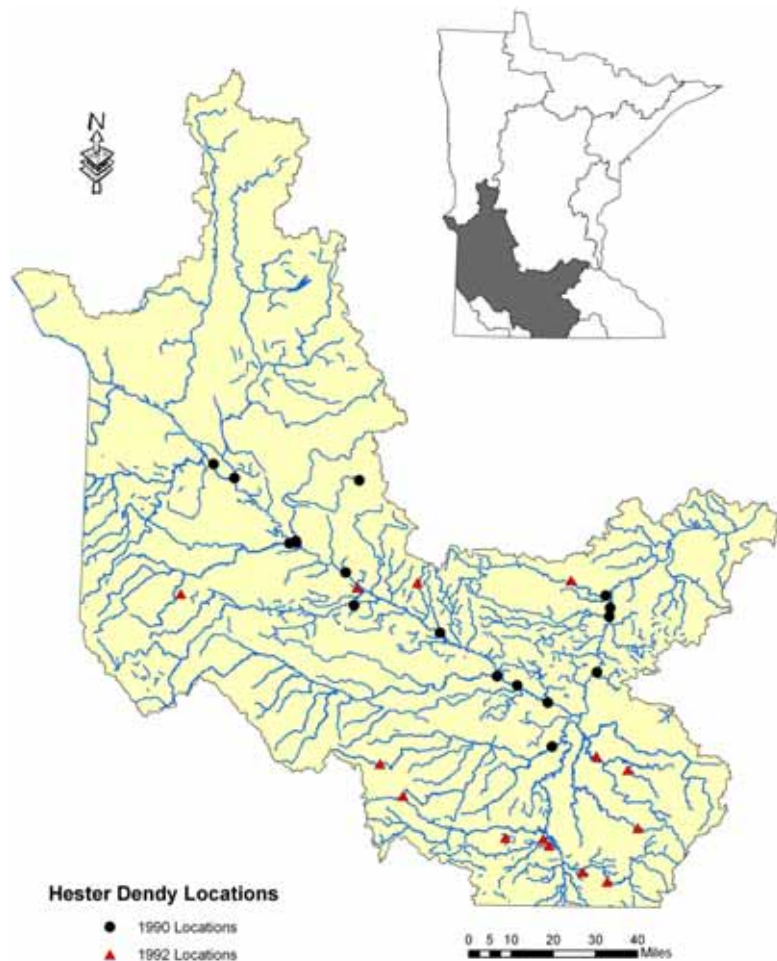


Figure 3: Map depicting the revisited Hester-Dendy locations within the Minnesota River Basin.



Habitat

Each site was also evaluated qualitatively for habitat condition. The habitat survey was accomplished by completing the Qualitative Habitat Evaluation Index, (QHEI). The QHEI rates the condition of the habitat in terms of surrounding land use, riparian vegetation, shade, bank condition, channel morphology, substrate, instream cover, water depth, and channel stability. To complete the QHEI, the stream was walked and measurements of stream width, depth, and length by channel type were recorded qualitatively; as well as observations of specific habitat attributes. At some sites, it was difficult to thoroughly assess the instream channel, substrate, and cover attributes. For these sites, which were the majority of the boom shocking sites, a QHEI score was not determined during the original MRAP sampling (Bailey et al. 1993). However, during the most recent sampling QHEI scores were determined for all sites.

In addition to a habitat evaluation, field water chemistry was also collected at each site using a Hach meter (model HQ40d). The following parameters were measured and recorded: dissolved oxygen, pH, conductivity ($\mu\text{S}/\text{cm}$), transparency, water temperature ($^{\circ}\text{C}$), and air temperature ($^{\circ}\text{C}$).

Water chemistry

Field water chemistry and grab samples for lab analysis were collected for the Minnesota River Assessment Project (MRAP) subset study (2001-2010). However, due to the limited sample size and insufficient characterization of the previous MRAP sites, the data were not appropriate for inclusion in the present report. For a current perspective on water quality changes within the Minnesota River Basin please refer to Musser et al. (2009).

Site and data evaluation

Recent improvements in sampling techniques and data analyses have led to a better and more accurate understanding of fish and invertebrate community assemblages. Using these newer methods, the MPCA developed new statewide IBIs for both fish and benthic macroinvertebrates. These IBIs were then used to score all fish and benthic macroinvertebrate sampling sites for both the MRAP comparison study (1990-92 vs. 2009-10) and the study of the subsets of MRAP sites (2001 vs. 2010).

Invertebrate trend analysis

During the previous MRAP, a total of 41 sample locations were visited between 1989 and 1992 (Zischke et al. 1994). In 2009, 33 of the previous MRAP locations were revisited for benthic macroinvertebrate collection (Figure 3). Because sites visited between 1989 and 1990 were statistically significantly larger (median watershed area 3,091 mi.²) than those sites visited between 1991 and 1992 (median watershed area 11 mi.²) (Independent two sample t-test, $p < 0.05$), the data were separated into two groups based on watershed drainage area. Watershed area often influences richness and diversity of many benthic macroinvertebrate communities, due to food availability, hydrologic variability, and available habitat. Therefore, smaller streams were separated from the larger streams in order to determine changes in community structure due to differences in ecological condition.

Furthermore, Hester-Dendy data from 1989 were removed from the analysis due to drought conditions in 1989, which may provide misinterpretation during trend analysis (Figure 4). Drought is a substantial abiotic factor which regulates many lotic ecosystems (*see references* in Resh et al. 1988); therefore removal of these data was critical to maintain congruency in data analysis. Also, samples from the Blue Earth River and Le Sueur River were omitted from data analysis because there were no comparisons between 1990 and 2009 for these locations. Finally, data from 1991 were removed from analysis due to small sample size ($n = 6$). Because both parametric paired t-tests and non-parametric Wilcoxon sign-rank tests are constrained to pairwise comparisons, a small sample would have limited the robustness of the analysis (Quinn and Keough 2002).

Since the previous study, there have been advancements in benthic macroinvertebrate identification techniques, and because of this, several genera and species identified during the current study were not identified during the previous study (Zischke et al. 1994). In order to maintain appropriate comparisons, the current dataset was constrained to the taxonomic resolution of the previous study (Zischke et al. 1994). In some cases this meant conducting comparisons based on broader levels of taxonomic proficiency (i.e. order and family). Secondly, raw data from the previous study were not available and comparisons between years were often based on averaged data for a given site and organism. Due to this constraint, samples were pooled to allow for comparisons between years.

Figure 4: Bar graph depicts the mean (± 2 S.E.) drainage area (mile²) for sites sampled within the Minnesota River Basin during a given year. Years with different letters indicate a statistically significant difference (independent two sample t-test, $p < 0.05$).

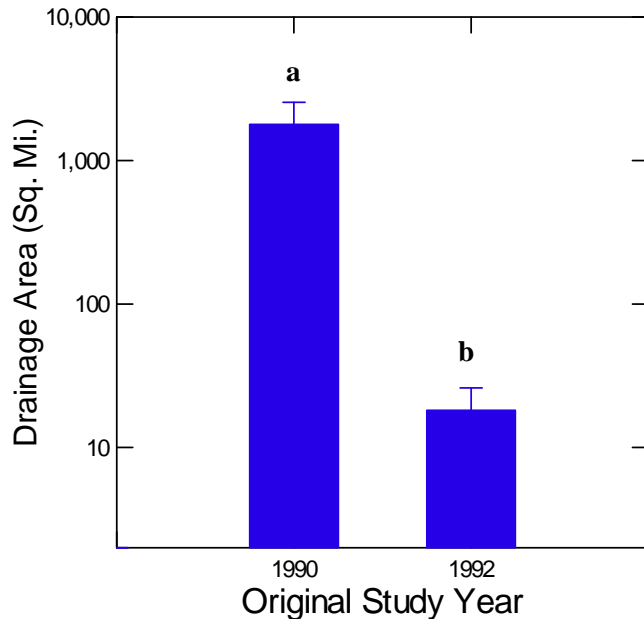
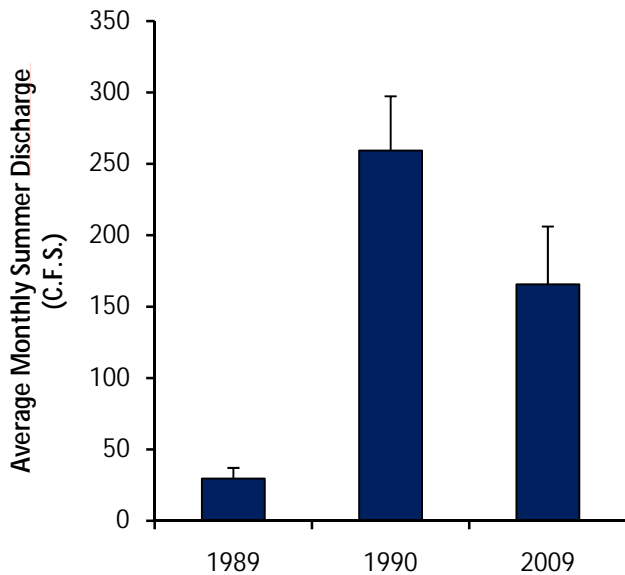


Figure 5: Mean summer (July-September) monthly discharge (\pm S.E.) for eight USGS gauging stations within the Minnesota River Basin.



Macroinvertebrate metrics

Many of the metrics used in the previous study were recalculated in order to provide direct comparisons with the findings from the previous study (Zischke et al. 1994). However, because biological monitoring is not a static process, several metrics have been added or altered based on the evolution of biological monitoring since the previous study (Carter et al. 2006). The paragraphs below contain a list of the metrics utilized for determining ecological condition.

Tolerance metrics

Macroinvertebrate biotic index

Many benthic macroinvertebrates found in Minnesota have an assigned tolerance value based upon the organism's response to a measure of stress (Hilsenhoff 1987; Lenat 1988; Barbour et al. 1999; Carter et al. 2006; Merritt et al. 2008). Tolerance values range from 0 (very intolerant) to 10 (most tolerant). In general, tolerance values are assigned at specific taxonomic levels, and in the present study we assigned tolerance values based on the lowest taxonomic level of identification. The macroinvertebrate biotic index (MBI) represents a score from 0 to 10, which is based on the average tolerance score within a given community, weighted by abundance (see equation below). The MBI score may be used to interpret the ecological condition at a given site (Table 1). Zischke et al. (1994) previously reported that an MBI score of 2.5 represented non-impacted streams while a site with an MBI score of 3.5 or greater represented an impacted stream. It is important to note that many of the tolerance values used in the previous report (Zischke et al. 1994) were updated in this study based on the Midwestern classification of benthic macroinvertebrate tolerance values (Barbour et al. 1999). Therefore, the results of the previous benthic macroinvertebrate community assessments have been updated to reflect the inclusion of the current tolerance values (Table 1).

$$MBI = \frac{\sum_{i=1}^s ni \times ti}{\sum_{i=0}^s ni}$$

Where ni represents the number of individuals and ti represents the tolerance value of the i th species, respectively, and s = the number of genera used for analysis (adapted from Hilsenhoff 1988 and Carter et al. 2006).

Table 1: Ecological condition based on the benthic macroinvertebrate biotic index values (adapted from Hilsenhoff 1988 and Carter et al. 2006).

Macroinvertebrate Biotic Index	Ecological Condition
0.00 - 3.75	Excellent
3.76 - 4.25	Very good
4.26 - 5.00	Good
5.01 - 5.75	Fair
5.76 - 6.50	Fairly poor
6.51 - 7.25	Poor
7.26 - 10.00	Very poor

Percent tolerant taxa

The relative abundance of tolerant taxa (tolerance value of 5 to 10) provides a measure of the proportion of pollution tolerant species within a given community. Tolerant taxa were designated as those individuals with a tolerance value of 5 or greater. In many streams, the relative abundance of tolerant organisms provides a measure of degradation within a given stream. Tolerant taxa are commonly found at most sites; however they tend to dominate at sites with degraded conditions (Fore et al. 1996). These sites tend to be characteristic of areas with low dissolved oxygen, heavy siltation, and high turbidity.

Percent intolerant taxa

The relative abundance of intolerant organisms provides a measure of the sensitive species within a given community. The metric is based on the abundance of benthic macroinvertebrates with tolerance values ranging from zero to two relative to the abundance of the community at a given site.

Community metrics

Community metrics provide a description of the benthic macroinvertebrate community expressed as the relative abundance of a given taxonomic group or combination of taxonomic groups. The metrics may be used to develop relationships with many abiotic and biotic factors affecting macroinvertebrate communities. The paragraphs below provide a list of macroinvertebrate community metrics used for past and present comparisons.

Percent Ephemeroptera, Plecoptera, and Trichoptera (EPT)

Many species of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) are known to be sensitive to many different environmental stressors (fluctuations in flow and temperature) as well as pollution (inorganic elements, pesticides, and emerging contaminants). Many of the individuals that make up these orders require moderate to high amounts of dissolved oxygen and are usually found in flowing waters. These organisms occupy many different components of the food chain and provide a sensitive indication of the overall condition of a given site.

Percent other Diptera and non-insect taxa

The relative abundance of non-tanytarsini Diptera and non-insect taxa provides a measure of adverse conditions, as these organisms are considered to be pollution tolerant (Zischke et al. 1994).

Macroinvertebrate index of biological integrity

The history of IBI development and use at the MPCA has been described by Chirhart (2003). In general, an IBI utilizes a series of metrics that are established based on biological responses to a measure of anthropogenic disturbance. The MPCA uses several statistically stringent criteria during the metric selection process to achieve an unbiased index. The end result is an IBI that allows for the interpretation of biological data to understand how biological communities respond to environmental stressors. Whitter et al. (2007) provides an overview of the statistically stringent criteria used by the MPCA.

Data Analysis

In order to compare results over the 10 and 20 year time periods, several statistical analyses were employed to determine changes in both fish and benthic macroinvertebrate communities. Paired t-tests were used to compare mean metric scores between time periods when data met normality assumptions (normal distribution and homogeneity of variance) or could be transformed (i.e. log10, square root) in order to meet the

assumptions. When normality assumptions were not met, a Wilcoxon sign-rank test was used for non-parametric comparisons between years. Secondly, a simple linear regression and Spearman rank correlation was used to interpret the relationship between variables (i.e. BMP, CREP, and landuse) and biological metrics. All data analyses and graphs were developed using SYSTAT version 13.1 statistical software.

Twenty Year Basin Study Results

Fish communities

1990-92 vs 2009-2010 MRAP protocol

Although 114 of the original 117 MRAP sites were sampled between 2009 and 2010 (Figure 7), 108 were used for analysis (See Appendix 1). Five of these sites were determined to be coldwater influenced. Currently, the MPCA does not have an IBI to determine biological condition within coldwater sites. Therefore, the 5 sites were removed from the proceeding analysis. The remaining site was not used since it was sampled during above normal flow conditions.

Overall, a statistically significant improvement in mean IBI score of 6.34 points was observed between the two time periods (paired t-test or Wilcoxon sign-rank test, $p < 0.05$) (Figure 6). Also, QHEI scores increased by an average of 6.58 points, which was statistically significant (paired t-test or Wilcoxon sign-rank test, $p < 0.05$).

Results comparing these two time periods for fish community assemblage (Figure 6) and instream habitat (See Appendix 2) are broken down into the three classifications used to describe streams in southern Minnesota.

Class 1 - southern rivers (drainage area > 300 mi²)

The largest rivers involved in the MRAP sampling showed an improvement in IBI at 17 of the 33 sites, while a decline was shown at 15 sites and 1 site showed no change (See Appendix 1). The average improvement in IBI score was just above 12 points with the Minnesota River near Judson leading the way with a 30 point increase in IBI score. The average decline in IBI score was just over 11 points. Overall, Class 1 sites saw an average improvement of 1.24 points which was not enough to be considered statistically significant (Figure 6).

Qualitative Habitat Evaluation Index scores improved between the two time periods. A statistically significant average increase of 9 points was observed (paired t-test or Wilcoxon sign-rank test, $p < 0.05$) (See Appendix 2).

Class 2 - southern streams (drainage area >30 mi² and < 300mi²)

Forty-one sites were classified as southern streams. Of these streams, 25 showed an improvement in fish IBI score (See Appendix 1), with an average increase in IBI score of 10.08 points. However, 15 sites observed a decrease in fish IBI score with an average decrease of 6.63 points. One site showed neither a gain nor loss in fish community health. Overall, Class 2 sites showed a nearly 3.72 point average increase in fish IBI score, which was statistically significant (paired t-test or Wilcoxon sign-rank test, $p < 0.05$) (Figure 6).

Qualitative Habitat Evaluation Index scores for this class showed a modest improvement between the two time periods. On average, a 7.4 point increase was seen at these sites. This improvement was statistically significant (paired t-test or Wilcoxon sign-rank test, $p < 0.05$) (See Appendix 2).

Class 3 - southern headwaters (drainage area <30 mi²)

The most improvements in IBI score were made at headwater sites. Nearly two-thirds of sites in this classification showed an increase in IBI score (See Appendix 1). Sites that increased raised their score an average of 19.79 points. County Ditch 26 in the Blue Earth River watershed had the largest increase in IBI score (53 point improvement) (See Appendix 2). The average decrease in IBI score was 11.14 points. Three sites within this class showed no decline or improvement over the 20 year difference between sampling. Altogether, Class 3 sites observed an average

increase in fish IBI score of 14.63, which was statistically significant (paired t-test or Wilcoxon sign-rank test, $p < 0.05$) (Figure 6). Class 3 sites showed the largest increase in QHEI scores. These sites had an average increase of over 15 points per site, which was statistically significant (paired t-test or Wilcoxon sign-rank test, $p < 0.05$) (See Appendix 2).

Figure 6: Bar graphs depicting 1990-92 and 2009-10 mean IBI score (\pm S.E.). A) IBI score separated by fish class (Southern Rivers $n=33$; Southern Streams $n=41$; Southern Headwaters $n=32$); B) IBI score for all fish classes combined. Years with similar letters do not indicate a statistically significant change in IBI scores (paired t-test or Wilcoxon sign-rank test, $p < 0.05$).

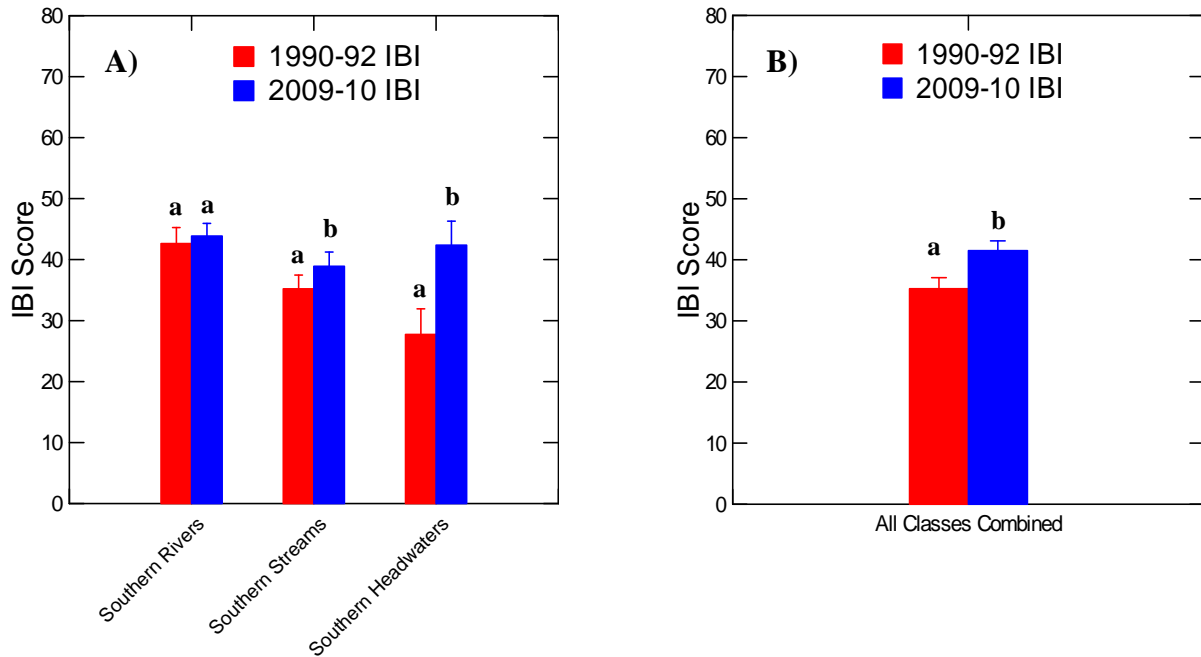
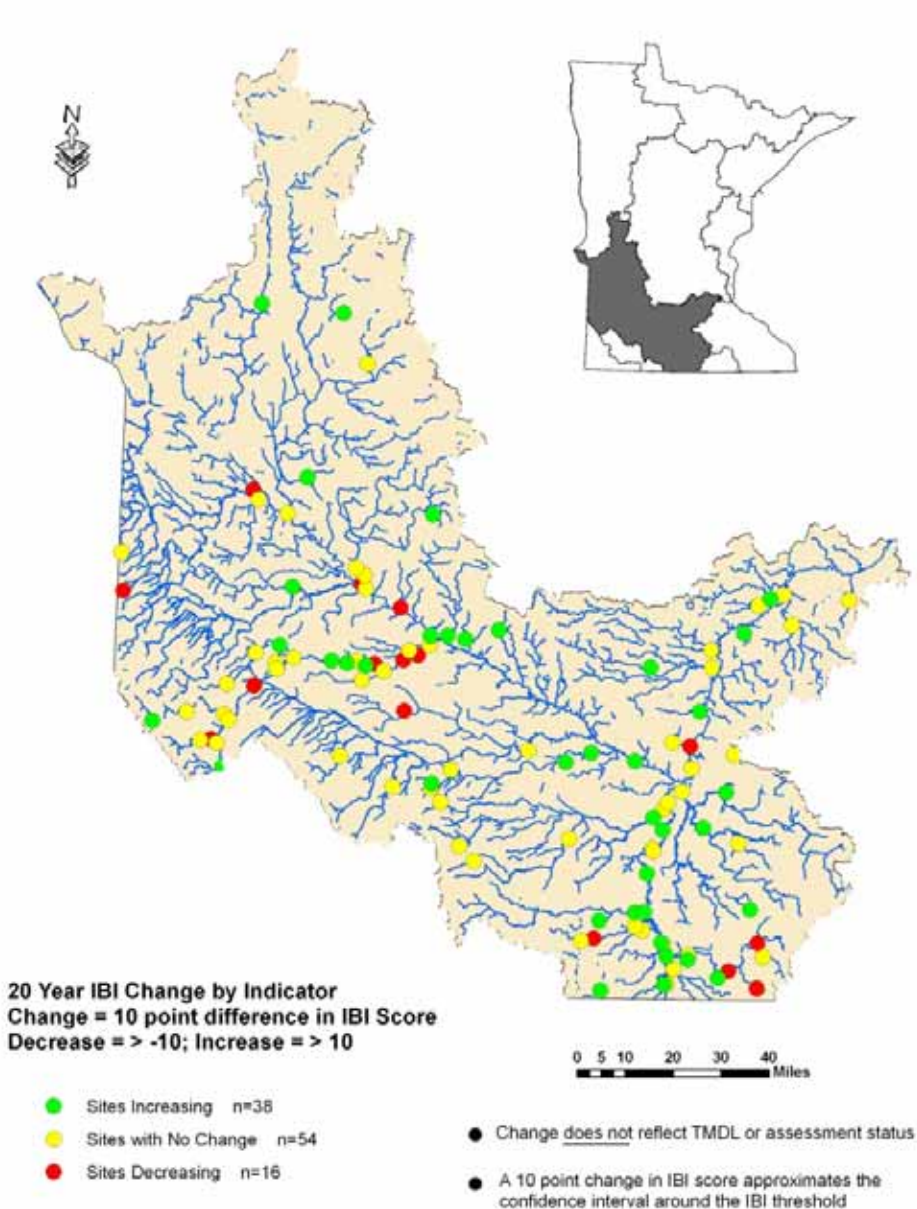


Figure 7: Spatial interpretation of the 20 year change in fish IBI sites resampled during the MRAP study using MRAP sampling protocols. Change, both positive and negative was based on a 10 point difference in fish IBI score.



Fish species of interest

While there has only been a minimal overall increase in fish IBI scores, an increase in traditionally large river sensitive species was noted. Blue sucker and black buffalo were two species that were not observed during the first sampling of MRAP, but were captured during the latest sampling. Shovelnose sturgeon collections increased from 11 individuals in the early 1990s to 19 during 2009-10. Throughout the basin observations of smallmouth bass increased from 24 individuals to 43 and walleye from 141 to 153. The return of and increased occurrences of these fish species is an encouraging sign for the Minnesota River since these species typically succeed in waters lacking fine sediments (Figure 8).

Figure 8: Clockwise from upper left: Blue Sucker from Minnesota River (90MN070), Shovelnose Sturgeon from Minnesota River (90MN070), Black Buffalo from Minnesota River (90MN070), and Smallmouth Bass from Minnesota River (90MN018).



This study also showed an increase in intolerant fish species. These species are more sensitive to degraded water quality conditions. Intolerant species showing an increase in population over the 20 years between MRAP projects include blacknose shiners, logperch, and mimic shiners. However, there was a significant decline in greater redhorse numbers between the two projects. Intolerant species found during the studies are pictured below in Figure 9.

Figure 9: Clockwise from upper left: Blacknose Shiner, Logperch, Mimic Shiner, and Greater Redhorse. (Photos courtesy of Konrad P. Schmidt).



Macroinvertebrate communities

Large river trends (1990 to 2009)

The dominant taxa collected from large river sites during the 2009 survey, in order of dominance were: *Glyptotendipes* (Diptera), *Hydropsyche* (Trichoptera), *Tricorythodes* (Ephemeroptera), *Cheumatopsyche* (Trichoptera), *Potamyia* (Trichoptera), and Oligochaeta. These taxa are similar to those of the 1990 survey in which the dominant taxa collected, in order of dominance were: *Hydropsyche* (Trichoptera), *Glyptotendipes* (Diptera), and *Gammarus* (Amphipoda) (Zischke et al. 1994). Dominant taxa were determined using the 95th percentile of total taxa collected for a given time period. This statistic was not constrained to taxa similar to both time periods. Of the dominant taxa collected from both years, most represent taxa considered to be ubiquitous within large warm water rivers. In addition, it has been demonstrated that many of these taxa are tolerant to environmental stress (*references in Merritt et al. 2008*).

There was no significant difference in tolerance measures between the two time periods; however a general increase in tolerant taxa and decline of intolerant taxa was observed in 2009 (Figure 10). Conversely, community metric comparisons indicated a statistically significant difference between the two time periods (Figures 11) (Wilcoxon sign-rank test, $p < 0.05$). Specifically, the change represents a decline in sensitive communities and an increase in communities tolerant of environmental stress. Nine of the 16 sites in this class observed modest improvement to minimal change in MBI score, while 7 sites observed an increase in MBI score (i.e. decrease in quality) over the 20 year periods (Figure 12 and Appendix 3). These data suggest approximately half of the previous sites sampled have observed modest improvement to little change, while the other sites have shown further degradation.

There was no correlation with best management practice (BMPs) as a percent of the watershed (per mile²) or BMP implementation since 1995 and changes in metric values or current metric values over the 20 year period (Spearman rank correlation, $p < 0.05$). Moreover, further analyses revealed no correlations with changes in CREP or landuse and changes in metric values or current metric values (Spearman rank correlation, $p < 0.05$).

Figure 10: Bar graphs depicting the mean (\pm S.E.) of tolerance metrics for large rivers between 1990 and 2009. A) MBI (n=16); B) percent tolerant taxa (n=16); C) percent very tolerant taxa (n=16); D) percent Intolerant Taxa (n=16). Years with differing letters indicate a statistically significant change (Wilcoxon sign-rank test, $p < 0.05$).

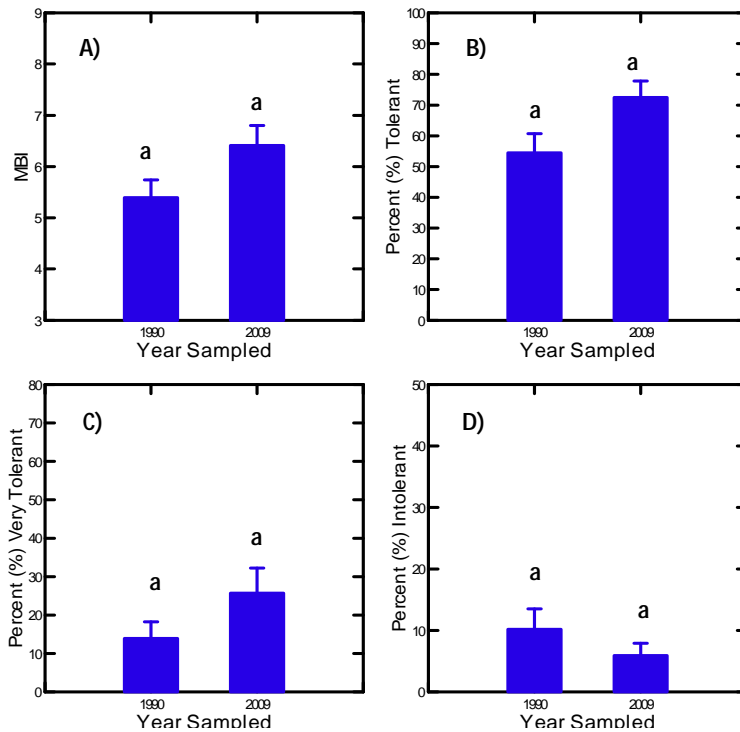


Figure 11: Bar graphs depicting the mean (\pm S.E.) of community metrics for large rivers between 1990 and 2009. A) Comparison of percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa (n=16); B) Comparison of percent Diptera and Non-insect taxa (n=16). Years with differing letters indicate a statistically significant change (Wilcoxon sign-rank test, $p < 0.05$).

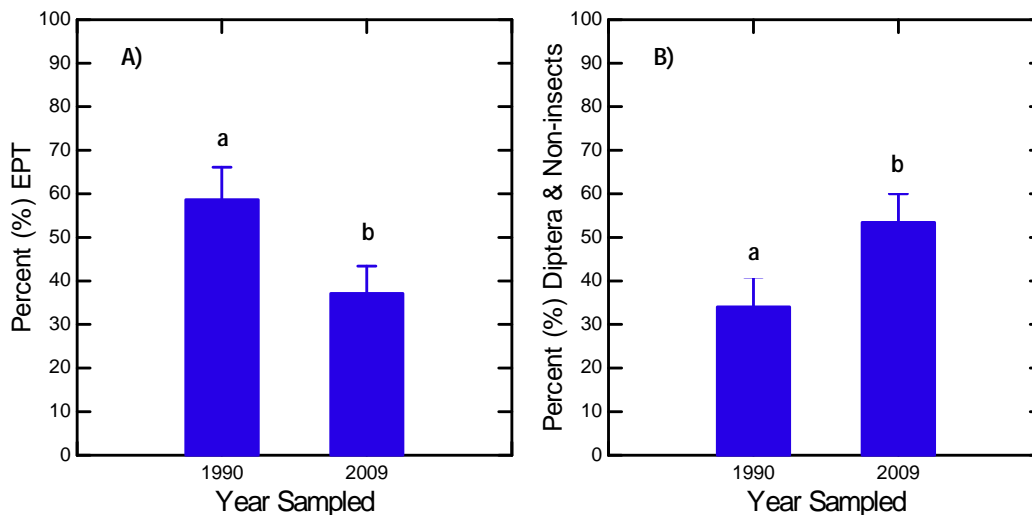
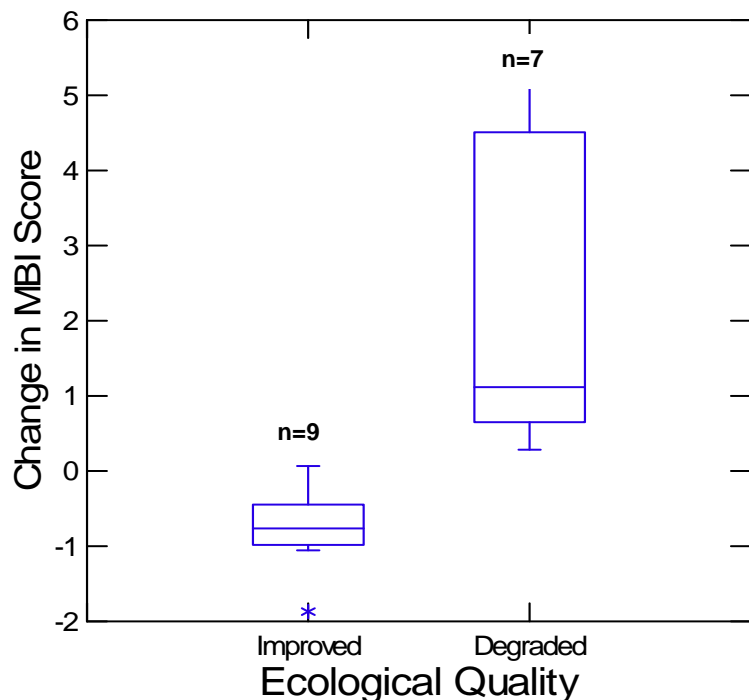


Figure 12: Box and whisker plot depicting the median (center line) and overall range (whisker boundaries) of change in MBI scores over the past 20 years, as well as the associated rating of ecological quality for large streams sampled in the Minnesota River Basin. An increase in MBI score indicates an increase in tolerant taxa, whereas a decrease in MBI score indicates a decrease in tolerant taxa.



Stream trends (1992 to 2009)

During the 2009 survey, the dominant taxa within streams of the Minnesota River Basin, in order of dominance were: *Glyptotendipes* (Diptera), *Stenelmis* (Coleoptera), *Physa* (Gastropoda), *Oligochaeta* (Annelida), and *Parakiefferiella* (Diptera). Many of the dominant species are known to be ubiquitous throughout lentic and lotic ecosystems, and indicate a stressed ecosystem as many of these genera are tolerant of environmental stress (Barbour et al. 1999). Conversely, the dominant taxa observed in streams during the previous study (1992), in order of dominance, were: *Hydropsyche* (Trichoptera), *Stenacron* (Ephemeroptera), *Stenonema* (Ephemeroptera), *Hyallela* (Ephemeroptera), and *Heptagenia* (Ephemeroptera). Although many of these dominant taxa represent EPT taxa, the specific genera that contributed to the metric have been shown to be tolerant of environmental stress (references in Merritt et al. 2008 and Barbour et al. 1999).

Both tolerance and community metric comparisons suggest that a majority of the sites sampled in small streams have degraded since the previous study (Figures 13 and 14). Twelve of the 16 sites (75 percent) represent channelized streams. Therefore, the degraded biological condition is not surprising given the stressors associated with channelized streams (i.e. lack of instream habitat, hydrologic modifications, continued maintenance of stream channel, and lack of riparian buffers) (Delong and Brusven 1998, Dovciak and Perry 2002, Lau et al. 2006). Moreover, three of the sites observed modest improvement or minimal change and 13 sites showed an increased degraded condition based on changes in MBI scores (Figure 15 and Appendix 3). No observed spatial patterns of MBI change were apparent following spatial interpretation (Figure 16).

There was no correlation with BMP implementation since 1995 and change in MBI score over the last 20 years for small rivers (Spearman rank correlation, $p < 0.05$). Moreover, upon further analysis, there was no correlation with the change in CREP as a percent of the watershed (per mile²) and changes in landuse with the 20 year changes in metrics or current metric scores; for all metrics respectively (Spearman rank correlation, $p < 0.05$).

Figure 13: Bar graphs depicting the mean \pm standard error of tolerance metrics for small rivers between 1992 and 2009. A) MBI (n=16); B) percent tolerant taxa (n=16); C) percent very tolerant taxa (n=16); D) percent intolerant taxa (n=16). Years with differing letters indicate a statistically significant change (Wilcoxon sign-rank test, $p < 0.05$).

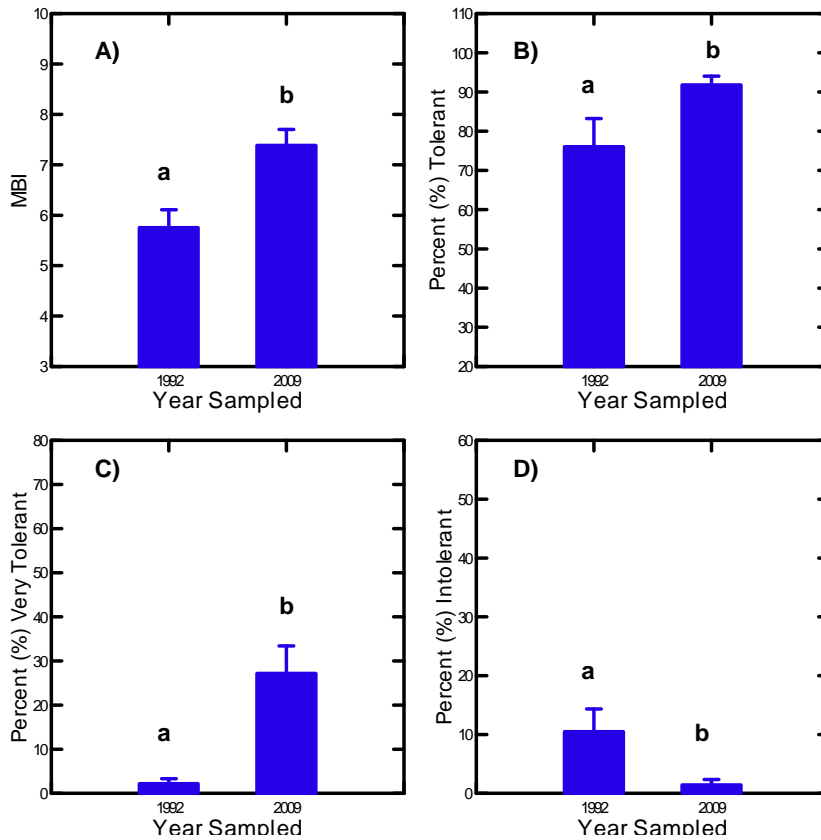


Figure 14: Bar graphs depicting the mean (\pm S.E.) of community metrics for small rivers between 1992 and 2009. A) Comparison of percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa (n=16); B) Comparison of percent Diptera and Non-insect taxa (n=16). Years with differing letters indicate a statistically significant change (Wilcoxon sign-rank test, $p < 0.05$).

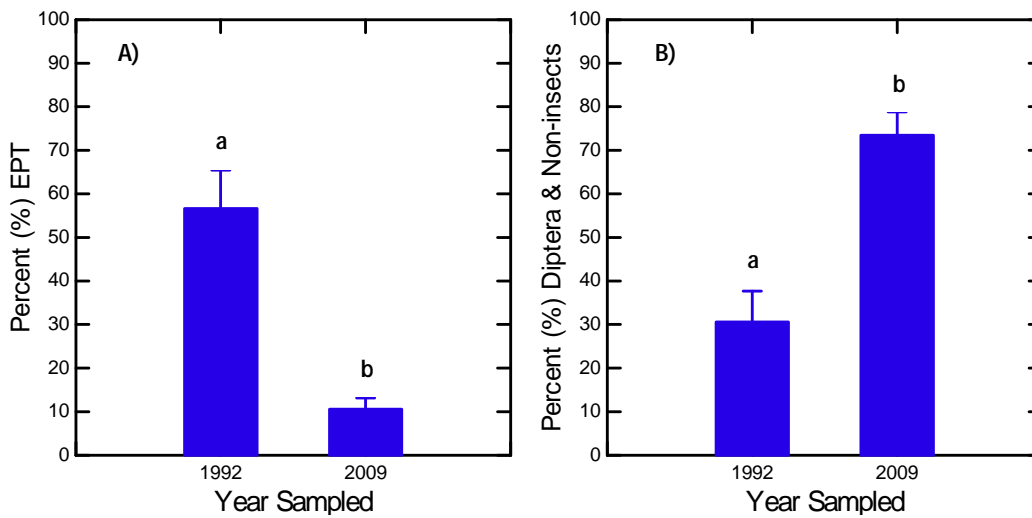


Figure 15: Box and whisker plot depicting the median (center line) and overall range (whisker boundaries) of the change in MBI scores over the past 20 years, as well as the associated rating of ecological quality for small streams sampled in the Minnesota River Basin. An increase in MBI score indicates a decrease in biological condition, whereas a decrease in MBI score indicates an improvement in biological condition.

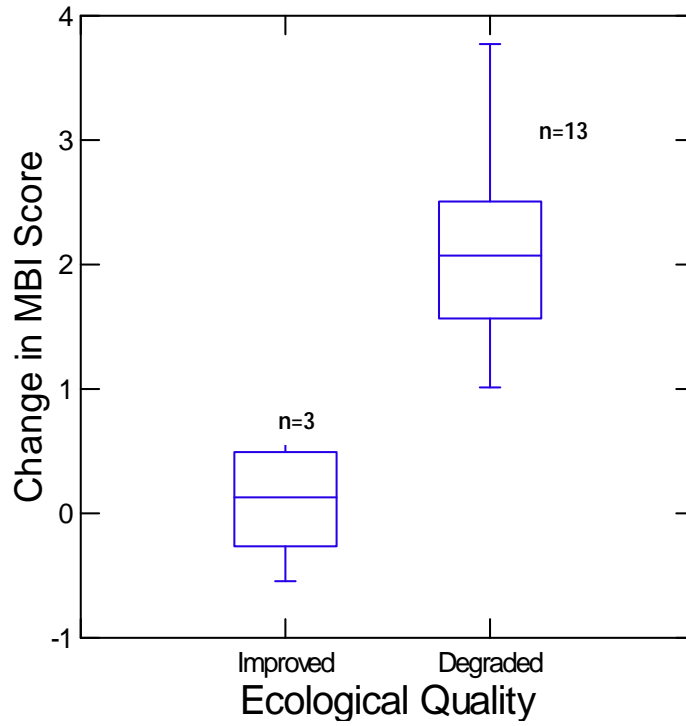
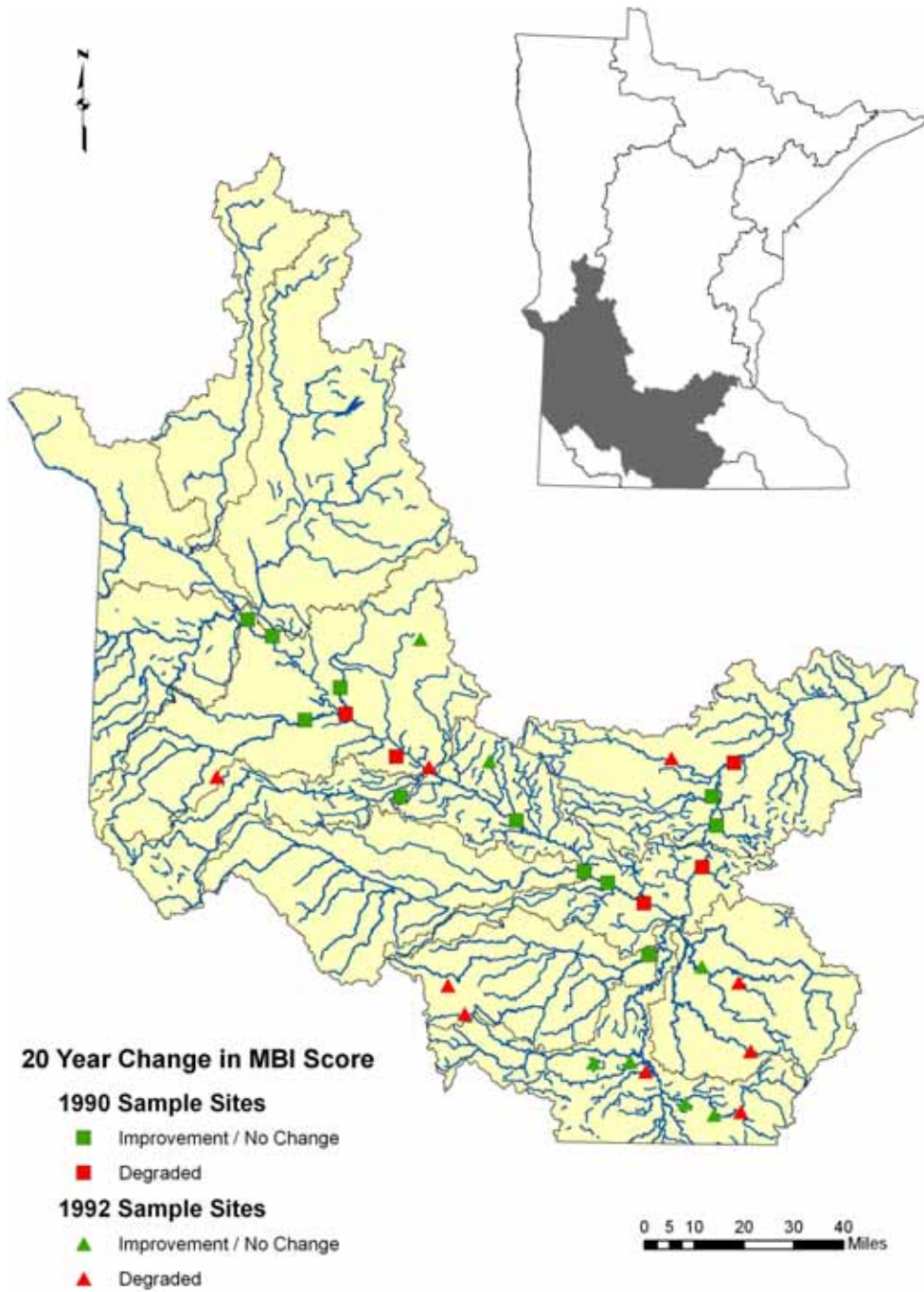


Figure 16: Spatial interpretation of 20 year change in MBI scores for small and large rivers sampled throughout the Minnesota River Basin. Change, both positive and negative, was based on a one point difference in MBI score.

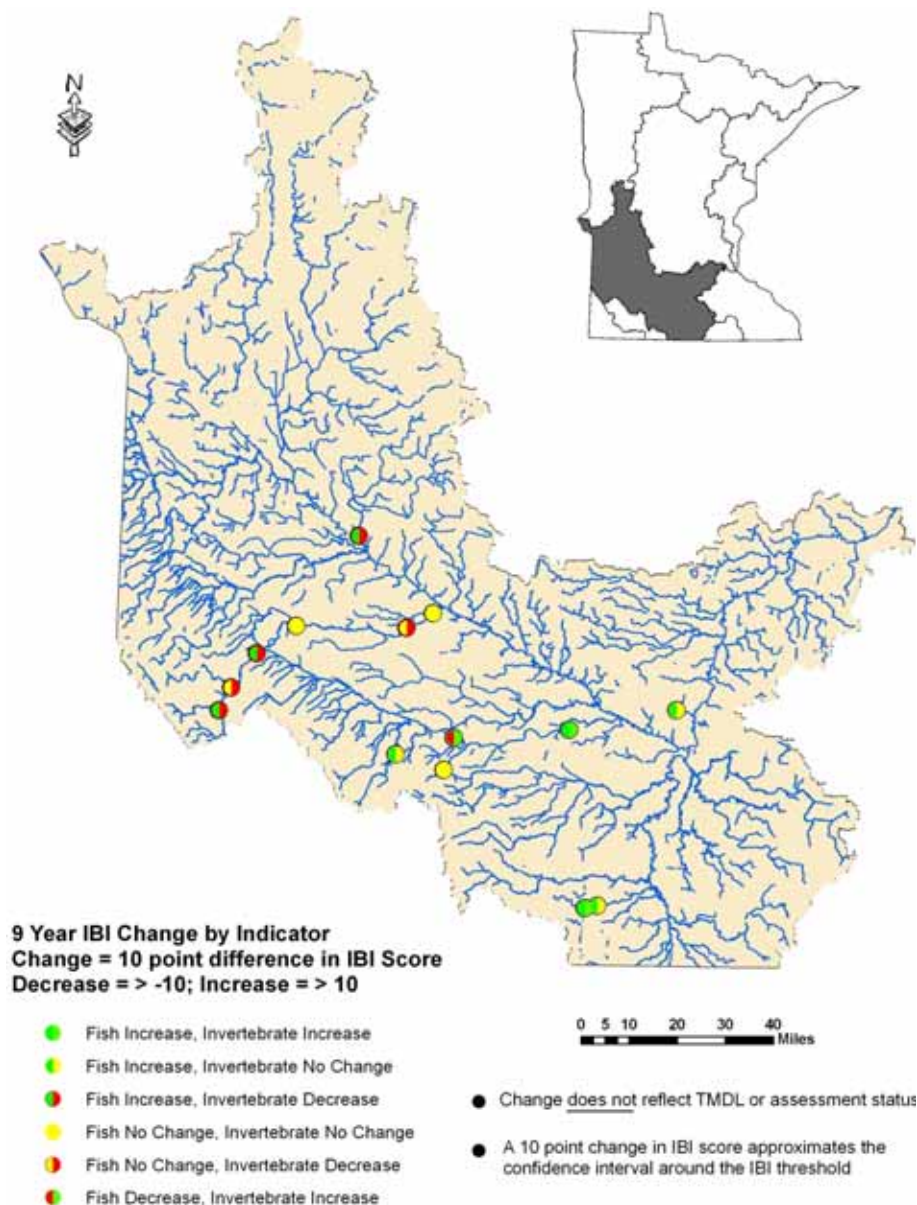


Nine Year Basin Study Results

2001 vs. 2010 MPCA protocol

In addition to the 20 year study using MRAP sampling methods, the MPCA replicated an MRAP progress study performed by the agency in 2001 using the more advanced fish and invert sampling protocols that the MPCA currently follows. See Figure 17 for a map illustrating the sites with both fish and invertebrate trend information available.

Figure 17: Spatial interpretation of the nine year change in both fish and benthic macroinvertebrate IBI score based on current MPCA sampling protocols. Change, both positive and negative was based on a 10 point difference in either fish or benthic macroinvertebrate IBI score, as this approximates the confidence limit surrounding the IBI threshold.



Index of biological integrity results

Fish community

Of the original subset of 31 sites, 27 were able to be re-sampled for fish community with 4 sites deemed unsamplable due to high flow conditions (See Appendix 1). The fish IBI scores using current MPCA protocols showed an overall increase in mean IBI score of 7.02 points which proved to be statistically significant (paired t-test or Wilcoxon sign-rank test, $p < 0.05$) (Figure 18).

The 27 sites represented three different fish IBI classes with the results described below:

Class 1- southern rivers (drainage area > 300 mi²)

Six sites of the 2001 MRAP subset were designated as southern rivers. Five of these sites showed an improvement with an average increase in IBI score of 10 points. The one site that declined dropped 1 point. The overall average difference in IBI scores between time periods was 8.08 points and was statistically significant (paired t-test or Wilcoxon sign-rank test, $p < 0.05$) (Figure 18).

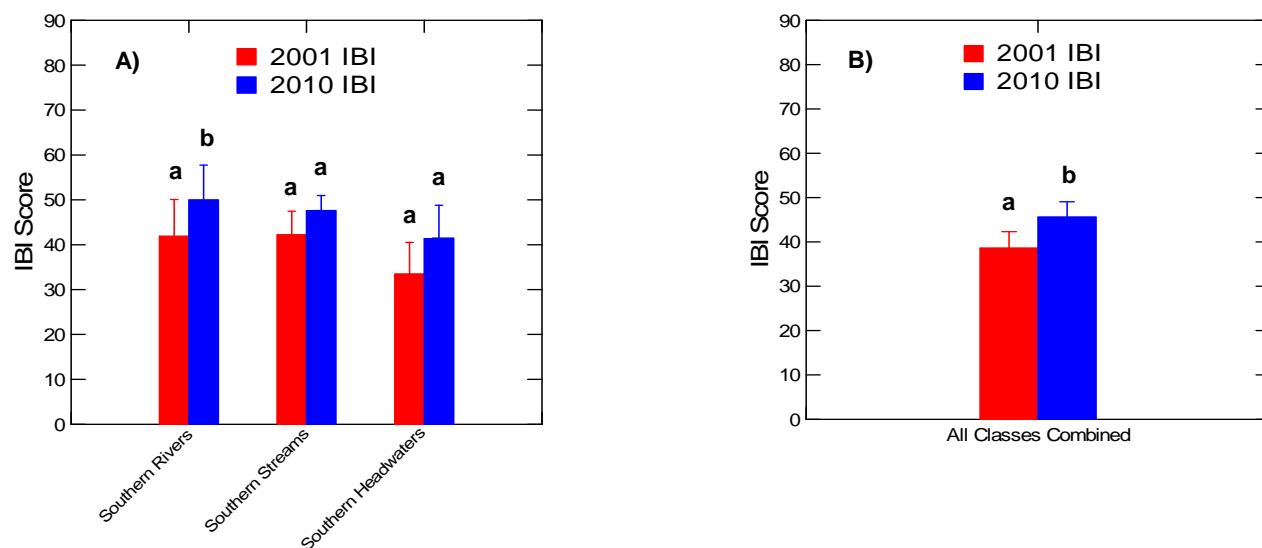
Class 2- southern streams (drainage area >30 mi² and < 300mi²)

There were 10 sites that fell into the southern stream class. The average increase in IBI score for the 8 sites demonstrating an improvement was 12.25. The IBI scores for the remaining 2 sites decreased by an average of 22 points. Spring Creek (Yellow Medicine watershed) observed the largest decline in IBI score (28 points). Overall, sites in this class showed an average improvement of 5.35 points; however the observed increase was not statistically significant (Figure 18).

Class 3 - southern headwaters (drainage area <30 mi²)

Eleven sites of the 2001 MRAP subset were classified as Southern Headwaters. IBI scores for 6 sites improved an average of 21 points. The IBI score for one of the 6, a tributary to Mound Creek improved by 74 IBI points. Index of biological integrity scores for 4 sites declined 9 points on average and one site showed no change in score at all since 2001. Overall streams within the southern headwaters class improved by an average fish IBI score of 7.95 points, but this increase it was not enough to be statistically significant (Figure 18).

Figure 18: Bar graphs depicting 2001 and 2010 mean IBI score (\pm S.E.). A) IBI score separated by fish class (Southern Rivers n=6; Southern Streams n=10; Southern Headwaters n=11); B) IBI score for all fish classes combined. Years with similar letters do not indicate a statistically significantly change in IBI scores (paired t-test, $p < 0.05$).



Macroinvertebrate community

From 2001 to 2010 there was no statistically significant difference in mean IBI score when all sites were combined (Figure 19), or when sites were separated based on invertebrate stream classification (paired t-test, $p < 0.05$) (Figure 20). Although there were no differences in mean IBI scores between the two sampling periods, a number of IBI scores within each class changed; Appendix 4 provides a list of the magnitude of change and aquatic life use designations for each site, respectively. A description of the class specific changes is provided in the following paragraphs.

Class 2 – prairie forest rivers (glide pool habitats)

The prairie forest rivers classification characterizes sites with a drainage area of greater than or equal to 500 square miles and that are characteristic of ecological provinces 222, 223, and 251 (MNDNR 2011). A total of 4 sites were sampled between 2001 and 2010, with an average change in IBI score of $-15 (\pm 18)$ points (See Appendix 4). All sites within this class had IBI scores that decreased, most notably the Redwood River, which observed a 41 point decrease in IBI score from 2001 to 2010. Three of the 4 sites within prairie forest rivers were rated fair, while the Redwood River was rated poor (See Appendix 4).

Class 5 – southern streams (riffle/run habitat)

The southern streams invertebrate classification characterizes sites within ecological provinces 222, 223, 251 (MNDNR 2011) and with drainage areas of less than 500 square miles. A total of 6 sites were sampled between 2001 and 2010, with an average change in IBI score of $-10 (\pm 12)$ points (See Appendix 4). Three sites, along the Redwood River, had a greater than 10 point decrease in IBI scores, while the other 3 sites (Center Creek, High Water Creek, and Little Cottonwood River) observed little to no change in IBI score. Based on the 2010 IBI score, 3 sites had aquatic life use (ALU) ratings of poor, 2 sites were rated fair, and 1 site rated good (See Appendix 4).

Class 7 – prairie streams (glide pool)

The prairie streams invertebrate classification characterizes sites with a watershed of less than 500 square miles and that are characteristic of ecological provinces 222 and 251 (MNDNR 2011). A total of 5 sites were sampled between 2001 and 2010, with an average change in IBI score of $8 (\pm 8)$ points (See Appendix 4). Index of biological integrity scores at 3 of the 5 sites improved (Center Creek, Mounds Creek, and tributary to Little Cottonwood River), and 2 sites observed little to no change (See Appendix 4). Based on 2010 IBI scores, 4 sites had ALU ratings of fair, with 1 site (County Ditch 46) with a poor rating.

Overall comparisons

When all sites were combined, the average change in IBI score was $-5 (\pm 15)$ points. Based on the 2010 IBI scores, 9 of the 15 sites received ALU ratings of fair, 5 sites received ALU ratings of poor, and 1 site (High Water Creek) received an ALU rating of good. Furthermore, between 2001 and 2010, IBI scores improved at 3 sites, 7 sites observed little to no change in IBI score, and 5 sites observed a greater than 10 point decrease in IBI score (See Appendix 4).

Figure 19: Bar graph depicting mean IBI score (\pm S.E.) for all sites sampled between 2001 and 2010 (n=15, p=0.196). Years with differing letters indicate a statistically significant change in mean IBI score (paired t-test, p < 0.05).

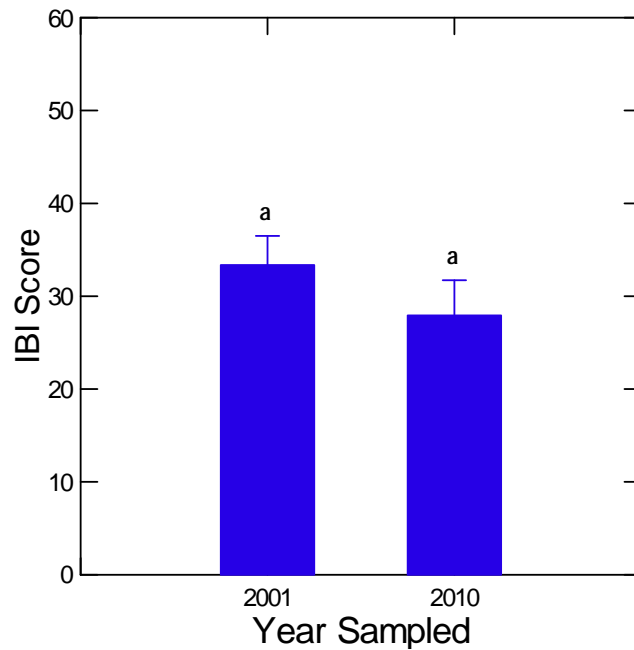
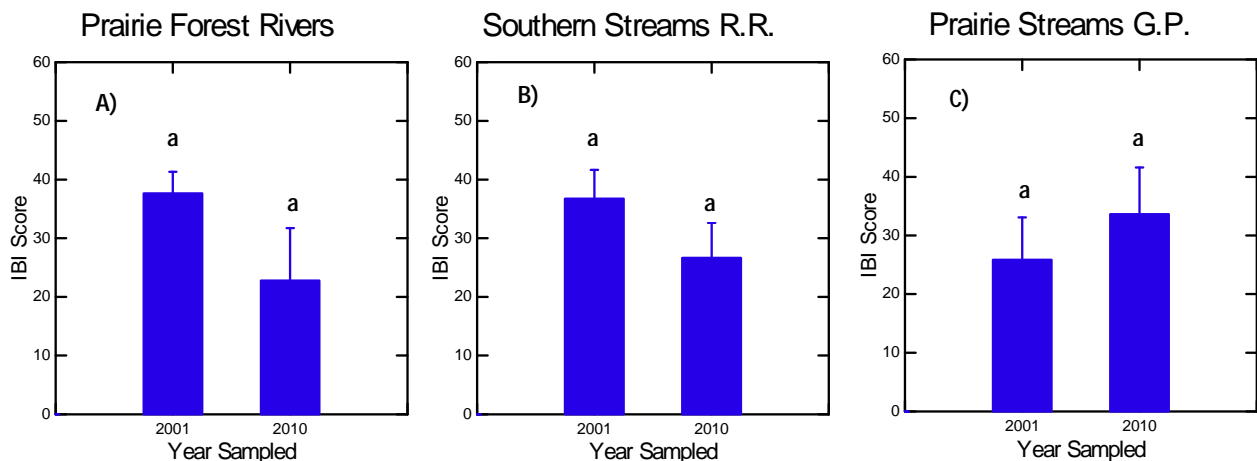


Figure 20: Bar graphs depicting mean IBI score \pm one standard error for sites sampled between 2001 and 2010. A) prairie forest rivers classification (n=4, p=0.193); B) southern stream rock rubble classification (n=6, p=0.103); C) prairie stream glide pool classification (n=5, p=0.10). Years with differing letters indicate a statistically significant change in IBI score (paired t-test, p < 0.05).



Minnesota Stream Habitat Assessment

The MPCA uses the Minnesota Stream Habitat Assessment (MSHA) as a way to determine the instream habitat conditions as opposed to the QHEI used for the original and follow-up MRAP sampling periods during this study. The MSHA was derived from the QHEI as a way to rate stream habitat conditions in Minnesota as opposed to the more generalized QHEI that originated from Ohio. The MSHA evaluations took place during the fish sampling visits; therefore the fish classification system is used when describing the results.

Minnesota Stream Habitat Assessment scores increased the most in the southern rivers streams. These scores increased 11.34 points on average. Sites within the Southern Streams and Southern Headwaters classes both experienced average increases of 5.21 and 0.71 points respectively. Habitat score improvements were statistically significant for the Southern Rivers class only. For site related habitat values, see Appendix 2. (paired t-test or Wilcoxon sign-rank test, $p < 0.05$).

Discussion and Conclusions

The 1990-1992 MRAP survey concluded that the biological condition of the Minnesota River Basin had been degraded over the years, which was attributed to a myriad of factors. In order to address the deteriorating conditions within the Basin, several advisory committees were formed, conservation programs were developed, and best management practices (BMPs) were implemented. To date, these efforts have led to only modest improvements to no change to the overall biological condition of rivers and streams within the Minnesota River Basin. The relatively small increase in overall fish IBI, the return of many intolerant fish species, and improvement of game species such as the smallmouth bass, are reasons to be optimistic about the future of biological conditions in the Minnesota River Basin. However, the lack of progress in benthic macroinvertebrate community health indicates that more conservation efforts are needed, and additional monitoring to better track the successes of these projects.

In heavily farmed landscapes like the Minnesota River watershed, many streams, particularly headwater streams, have been channelized to increase agricultural production by quickly and efficiently moving water from the fields to the stream. As of 2001, 78 percent of the Minnesota River Basin was in agricultural production, down 0.6 percent from 1992 (Musser et al. 2009). Although channel modification may provide benefits to farmers, there are prolonged effects to hydrologic processes and biological communities (Lau et al. 2006). These direct changes to the streams natural course may negate the effectiveness of watershed wide BMPs by directly altering the hydrology (Lau et al 2006), increasing fine sediments, nutrients, contaminants, and simplifying in-stream habitat (Waters 1995, Balogh et al. 1996, Nerbonne and Vondracek 2001). Under these modified conditions, the ecological potential of streams may be reduced as aquatic communities become dominated by a few highly adaptable, tolerant species of invertebrates and fish (*see references in* Lau et al. 2006).

Another known stressor to biological communities is the increase in urbanization and subsequent addition of impervious surfaces within a watershed. Aquatic ecosystems within close proximity to urbanized areas often have contributing runoff sources from impervious surfaces. These contributing sources are often characterized by poor water quality, degraded biological communities, and lack of instream habitat (Feist and Niemela 2002). Concerns in the Minnesota River Basin about impervious surfaces are generally restricted to the large or fast growing metropolitan areas like Mankato, as well as the outlet of the Minnesota River located in the Twin Cities Metropolitan Area. Limiting the effects from runoff caused by these surfaces will be a contributing factor to preventing further degradation to the biological communities within the Minnesota River Basin, as well as other basins in the state.

During the present study, two methods for assessing change in biological condition were compared. The results from the fish analyses indicate that there was a statistically significant, but modest, increase in biological condition over the 20 year period based on an increase in fish IBI scores. However, when IBI scores were analyzed, significant increases in biological condition were observed only in the southern streams and southern headwaters fish classes. Conversely, the results of the benthic macroinvertebrate analyses indicated that large and small river sites had significantly decreased biological condition over the 20 year period. While these two measures of ecological condition provide conflicting results, it should be noted that each respond to measures of stress differently. For example, both fish and invertebrates are mobile, which allows them to move when conditions warrant. However, fish are able to recolonize previous habitats quicker due to a rapid dispersal rate, while dispersal rates for invertebrates are much slower and depend on many factors (i.e. distance from source population, hydrologic conditions).

Based on Minnesota Board of Water and Soil Resources data, an increase in BMP implementation has been observed since 1995. However these data provide little supporting evidence that there has been a concomitant change in the biological condition throughout the Minnesota River Basin. One suggestion for the lack of supporting evidence is BMP implementation was not focused at or near MRAP site locations resulting in values that may not reflect the overall improvements of the watershed as a whole (Feist 2002). Increased accountability of BMP implementation will aid in the characterization of the effectiveness that these implementations have over time. Furthermore, targeted biological and water quality monitoring near BMP projects will provide interpretation of how specific BMPs affect overall water quality and biological condition.

Given the current transition to water quality monitoring via a watershed approach, the ability to track the effectiveness of BMP implementation may not be too far away. Currently, the MPCA conducts intensive biological and water quality monitoring within an average of eight 8-digit hydrologic unit code (HUC) watersheds each year. This process identifies monitoring locations for comprehensive monitoring using an unbiased method. Within each 8-digit HUC watershed, monitoring sites are sampled for biology, water chemistry, and habitat. These data are then used to make assessments about the condition of the watershed. Following the water body assessments, stressors that limit the aquatic community are identified. The assessment and stressor identification process allows for the development of specific plans to link impaired waters and/or waters suitable for protection with the appropriate BMPs. However, it should be noted that at this time BMP implementation is a voluntary process. Rates of BMP adoption are often low and not necessarily selected or placed in areas that will maximize the potential to achieve a desirable water quality result that can be linked back to the monitoring data. None the less, successive biological and water quality sampling following the 10 year watershed schedule will allow us to track changes in water quality much more effectively than we have in the past.

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Appendix

Appendix 1: MRAP Fish sampling locations and corresponding IBI scores. A 10 point change in IBI score approximates the confidence limits surrounding the IBI threshold for each class. Negative changes are highlighted in red and positive changes are in green. Fish IBI Classes (1 = Southern Rivers; 2 = Southern Streams; 3 = Southern Headwaters; 7 = Low Gradient)

Site #	Stream Name	Location	Watershed (HUC8)	Fish IBI Class	1990-92 IBI (MRAP)	2009-10 IBI (MRAP)	2001 IBI (MPCA)	2010 IBI (MPCA)	20 Year Change	9 Year Change
90MN071	County Ditch 44	Downstream of CR 19, 2 mi. SE of Frost	Blue Earth	3	19	56			37	
90MN073	West Branch Blue Earth River	Downstream of 40th St, 2.5 mi NW of Elmore	Blue Earth	2	31.5	48			16.5	
90MN077	Brush Creek	Upstream of 570th Ave, 0.5 mi W of Kiester	Blue Earth	3	60.5	47			-13.5	
90MN081	Judicial Ditch 38	Upstream of CSAH 49, 9 mi. SE of Fairmont	Blue Earth	3	1	11			10	
90MN094	Blue Earth River	Downstream of Hwy 169, 1 mi S of Vernon Center	Blue Earth	1	50	47			-3	
90MN101	Blue Earth River	Downstream of Rapidan Dam, Downstream of CR 9, in Rapidan	Blue Earth	1	60	48			-12	
90MN106	Blue Earth River	Upstream of CSAH 90, 1 mi. SW of Mankato	Blue Earth	1	51	43			-8	
91MN080	County Ditch 26	Upstream of CR 13, 3 mi. E of Blue Earth	Blue Earth	3	18	71			53	
91MN086	Judicial Ditch 3	Upstream of 240th Ave, 4 mi. NE of Fairmont	Blue Earth	3	0	18			18	
91MN089	County Ditch 60	Upstream of 370th Ave, 4 mi NW of Blue Earth	Blue Earth	3	14	43			29	
92MN072	Blue Earth River, Middle Branch	Downstream of 40th St., 2.5 mi N of Elmore	Blue Earth	2	34	27			-7	
92MN074	Coon Creek	Downstream of CR 4, 3 mi S of Blue Earth	Blue Earth	2	34	39			5	
92MN075	Blue Earth River, East Branch	Downstream of 100 St, 2 mi. NW of Walters	Blue Earth	2	22	24			2	
92MN076	Foster Creek	Upstream of CR 40, 4 mi. NW of Jordan	Blue Earth	2	23	19			-4	
92MN078	Blue Earth River, East Branch	Upstream of Co Hwy 21, 2 mi NW of Bricelyn	Blue Earth	2	41	39			-2	
92MN079	Blue Earth River, East Branch	Upstream of CR 13, 4 mi E of Blue Earth	Blue Earth	2	54	40			-14	
92MN082	South Creek	Upstream of 330th Ave, 4 mi. SW of Winnebago	Blue Earth	2	38	41			3	
92MN083	Center Creek	Downstream of North Ave, Fairmont treatment plant, in Fairmont	Blue Earth	2	18	18	29	36	0	7
92MN084	Center Creek	Upstream of 230th Ave, 2 mi E of Fairmont	Blue Earth	2	41	19	22	34	-22	12
92MN085	Center Creek	Upstream of CSAH 1, 4 mi. SW of Winnebago	Blue Earth	2	33	36			3	
92MN087	Elm Creek	Upstream of CSAH 1, 2.5 mi. W of Winnebago	Blue Earth	2	40	47			7	

Site #	Stream Name	Location	Watershed (HUC8)	Fish IBI Class	1990-92 IBI (MRAP)	2009-10 IBI (MRAP)	2001 IBI (MPCA)	2010 IBI (MPCA)	20 Year Change	9 Year Change
92MN088	Blue Earth River	Downstream of CSAH 6, 0.5 mi SW of Blue Earth	Blue Earth	1	21	41			20	
92MN090	Blue Earth River	Upstream of CSAH 8, 2 mi. NW of Blue Earth	Blue Earth	1	28	27			-1	
92MN091	Blue Earth River	Upstream of CSAH 12, 0.5 mi. W of Winnebago	Blue Earth	1	34	45			11	
92MN092	Blue Earth River	Downstream of CR 147, 1.5 mi SW of Amboy	Blue Earth	1	23	38			15	
92MN093	Blue Earth River	Downstream of Hwy 169, .5 mi S of Vernon Center	Blue Earth	1	31	37			6	
92MN095	Blue Earth River	Upstream of CSAH 13, 3 mi W of Good Thunder	Blue Earth	1	38	49			11	
92MN096	Blue Earth River	Adjacent to 185th St, 4 mi SE of Lake Crystal	Blue Earth	1	38	35			-3	
90MN008	Signalness Creek	Upstream of CR 41, near Glacial Lake State Park, 4.5 mi S of Starbuck	Chippewa	3	42	63	61	48	21	-13
90MN010	Chippewa River, East Branch	Swift County Park, in Swift Falls	Chippewa	2	58	63			5	
91MN013	Trib. to Dry Weather Creek	Downstream of 20th St NW, 7 mi NE of Montevideo	Chippewa	3	15	40			25	
90MN062	Plum Creek	Downstream of CR 78, in Plum Creek Cty Park, 1 mi. SW of Walnut Grove	Cottonwood	2	57	65			8	
90MN063	Highwater Creek	Downstream of CR 10, in Cottonwood Cty Park, 5.5 mi NW of Jeffers	Cottonwood	2	58	52.5	40	55	-5.5	15
90MN069	Cottonwood River	Upstream of 260th Ave, 4 mi. S of Sleepy Eye	Cottonwood	1	46	51			5	
91MN065	Trib. to Mound Creek	Downstream of 460th Ave, 4 mi S of Springfield	Cottonwood	3	28	74	8	82	46	74
91MN066	Mound Creek	Upstream of 490th Ave, 6.5 mi. NE of Jeffers	Cottonwood	3	65.5	55			-10.5	
91MN067	Mound Creek	Downstream of 420th Ave, 3.5 mi. S of Springfield	Cottonwood	2	20	34	68	47	14	-21
91MN068	County Ditch 54	Downstream of CR 66, 3 mi. SE of Wabasso	Cottonwood	3	42	17			-25	
92MN064	Trib. to Mound Creek	Off of 250th St, Downstream of Red Rock Falls, in County Park, 6.5 mi NE of Jeffers	Cottonwood	3	63	60			-3	
90MN002	West Fork Lac qui Parle River	Upstream of County Line Road, 1 mi NE of Gary, South Dakota	Lac Qui Parle	3	50	45			-5	
90MN003	Lazarus Creek	Upstream of CR E5, 7 mi. SW of Canby	Lac Qui Parle	3	53	30			-23	
90MN005	Ten Mile Creek	Downstream of CR 18, 5 mi NW of Montevideo	Lac Qui Parle	2	34	43			9	
90MN006	Lac qui Parle River	Downstream of confluence with Ten Mile Creek, 9 mi. NW of Montevideo	Lac Qui Parle	1	50	26			-24	
90MN105	Le Sueur River	West of CR 28, in Wildwood County Park, 3.5 mi. N of St. Clair	Le Sueur	1	32	45			13	
91MN102	Maple River	Downstream of Hwy 22, 2.5 mi NW of Wells	Le Sueur	3	22	46			24	

Site #	Stream Name	Location	Watershed (HUC8)	Fish IBI Class	1990-92 IBI (MRAP)	2009-10 IBI (MRAP)	2001 IBI (MPCA)	2010 IBI (MPCA)	20 Year Change	9 Year Change
91MN103	County Ditch 5	Upstream of Twp Rd 316/620th Ave, 3 mi SW of Pemberton	Le Sueur	7	0	9			9	
91MN104	Trib. to Big Cobb River	Upstream of Hwy 22, 5.5 mi E of Good Thunder	Le Sueur	3	0	33			33	
90MN110	Rush River	Adjacent to Rush River Park Road, in the Rush River Unit of Minnesota Valley Trail SP, 2 mi SW of Henderson	Lower Minnesota	1	28	40.5			12.5	
90MN111	Buffalo Creek	Upstream of 270th St, 2 mi NW of Henderson	Lower Minnesota	3	41.67	45	54	48	3.33	-6
90MN113	Silver Creek	Downstream of CR 41, 5 mi NE of Belle Plaine	Lower Minnesota	2	33.5	38.5			5	
90MN114	Bevens Creek	Upstream of CR 40, 4 mi. NW of Jordan	Lower Minnesota	2	52	61			9	
90MN115	Minnesota River	Off of CR 50, 3 mi downstream of Jordan access, 4 mi. N of Jordan	Lower Minnesota	1	45	53			8	
90MN116	Sand Creek	Upstream of W 220th St, 3 mi. SE of Jordan	Lower Minnesota	2	38	52			14	
90MN117	Credit River	Upstream of Murphy Lake Blvd (CR 75), 3.5 mi E of Prior Lake	Lower Minnesota	3	58.33	56	61	53	-2.33	-8
91MN109	County Ditch 43	Upstream of 310th St 4 mi. SE of Gaylord	Lower Minnesota	3	29	70			41	
91MN112	Robert Creek	Downstream of Oak Crest Trail, 1mi SW of Belle Plaine	Lower Minnesota	3	15	59	42.5	51	44	8.5
90MN053	Birch Coulee Creek	Upstream of Unnamed road, in Birch Coulee Battlefield park, 2 mi. N of Morton	Minnesota River-Mankato	2	32	39			7	
90MN058	Little Cottonwood River	Downstream of Hwy 15, 4 mi S of New Ulm	Minnesota River-Mankato	2	40.5	57			16.5	
90MN070	Minnesota River	Upstream of Hwy 23, 3 mi NW of Judson	Minnesota River-Mankato	1	34	66			32	
90MN107	Minnesota River	Downstream of Hwy 14, 1 mi downstream of power plant in Mankato	Minnesota River-Mankato	1	56	54.5			-1.5	
90MN108	Minnesota River	Adjacent(east) of Hwy 169, 6 mi N of North Mankato	Minnesota River-Mankato	1	63	44			-19	
91MN054	County Ditch 106A trib	Upstream of 420th St, 5 mi. NE of Franklin	Minnesota River-Mankato	7	4	15			11	
91MN056	Little Cottonwood River	Upstream of CR 2, 7 mi. E of Jeffers	Minnesota River-Mankato	3	51	52	50	53	1	3
91MN057	Little Cottonwood River trib	Upstream of 170th St, 5 mi. NW of Hanska	Minnesota River-Mankato	3	29	62	35	58	33	23
91MN059	County Ditch 46A	Upstream of township road 186/411th Ave, 6.5 mi W of Kasota	Minnesota River-Mankato	3	0	0	6	17	0	11
91MN060	Duck Lake outlet	downstream from Co Rd 16, 2.5 mi. N of Madison Lake	Minnesota River-Mankato	3	59	65			6	
91MN061	Rogers Creek	Downstream from CSAH 20, 3 mi N of St. Peter	Minnesota River-Mankato	3	0	23	32	21	23	-11
90MN001	Pomme de Terre River	Morris City Park, off Hwy 10, 2 mi SE of Morris	Pomme de Terre	1	31	47			16	

Site #	Stream Name	Location	Watershed (HUC8)	Fish IBI Class	1990-92 IBI (MRAP)	2009-10 IBI (MRAP)	2001 IBI (MPCA)	2010 IBI (MPCA)	20 Year Change	9 Year Change
91MN040	County Ditch 33	Downstream of Fairview Ave, 1.5 SE of Vesta	Redwood	3	15	41			26	
92MN021	Redwood River	Downstream of CR 80, below small dam, 2 mi NW of Current Lake	Redwood	2	56	44			-12	
92MN022	Redwood River	Downstream of Hwy 14, 2 mi E of Florence	Redwood	2	37	37	36.5	47	0	11
92MN023	Tyler Creek	Upstream of Hwy 14, 3 mi. SE of Tyler	Redwood	2	20	12			-8	
92MN024	Tyler Creek	Upstream of Hwy 23, 1 mi NE of Florence	Redwood	2	38	27			-11	
92MN025	Redwood River	Upstream of Hwy 23, 0.5 mi. SW of Russel	Redwood	2	39	57	39	42	18	3
92MN026	Norwegian Creek	Upstream of Hwy 75, 2.5 mi. N of Lake Benton	Redwood	3	7	37			30	
92MN027	Coon Creek	Upstream of CR 113, 3.5 mi. N of Tyler	Redwood	2	0	27			27	
92MN028	Coon Creek	Upstream of CR 66, 6 mi. SW of Lynd	Redwood	2	45	29			-16	
92MN030	Redwood River	Downstream of CR 74, 3 mi. SW of Marshall	Redwood	2	60	45	42	48	-15	6
92MN031	Redwood River	Adjacent to CR 67, 1 mi. NW of Marshall	Redwood	2	49	49	39	43	0	4
92MN032	Redwood River	Adjacent to 300th St, 2 mi. N of Marshall	Redwood	2	53	51			-2	
92MN033	Redwood River	Adjacent to 300th Ave, 5 mi. NE of Marshall	Redwood	1	13	17	23	30	4	7
92MN034	Three Mile Creek	Upstream of CR 57, 9 mi. W of Marshall	Redwood	3	68	65			-3	
92MN035	Three Mile Creek	Upstream of 220th Ave, 5.5 mi. NW of Marshall	Redwood	2	45	56			11	
92MN036	Three Mile Creek	Upstream of 270th Ave, 6 mi. N of Marshall	Redwood	2	15	47			32	
92MN037	Redwood River	Downstream of CR 51, 5 mi. NW of Milroy	Redwood	1	34	47			13	
92MN038	Redwood River	Upstream of CSAH 8, 6 mi. W of Vesta	Redwood	1	9	32	32.5	49	23	17
92MN039	Redwood River	Upstream of Hwy 19, 0.5 mi. SW of Vesta	Redwood	1	38	34			-4	
92MN041	Redwood River	Upstream of CR 56, 3 mi. SE of Vesta	Redwood	1	34	25	34	45	-9	11
92MN042	Clear Creek	Downstream of 270th Ave, 2 mi N of Lucan	Redwood	2	22	20			-2	
92MN043	Clear Creek	Downstream of 290th St, .5 mi. SE of Seaforth	Redwood	2	27	29			2	
92MN044	Redwood River	Upstream of CSAH 6, 6 mi. SW of Redwood Falls	Redwood	1	34	25.5	24	29	-8.5	5
92MN045	Redwood River	Downstream of CSAH 17, 2 mi. SW of Redwood Falls	Redwood	1	51	30			-21	
92MN046	Ramsey Creek	Downstream of Justice Ave, 4 mi. W of Redwood Falls	Redwood	2	12	8			-4	

Site #	Stream Name	Location	Watershed (HUC8)	Fish IBI Class	1990-92 IBI (MRAP)	2009-10 IBI (MRAP)	2001 IBI (MPCA)	2010 IBI (MPCA)	20 Year Change	9 Year Change
92MN049	Redwood River	Downstream of E Oak St, in Ramsey park, in Redwood Falls	Redwood	1	57	49	73	68	-8	-5
90MN099	South Fork Watonwan River	Downstream of Hwy 60 at Wayside Rest, 5 mi. E of St. James	Watonwan	2	27	36	45	56	9	11
90MN100	Watonwan River	Upstream of Washington St in Garden City	Watonwan	1	36	60			24	
91MN097	Judicial Ditch 1	Downstream of CR 1, in wayside park, 2 mi. S of Mountain Lake	Watonwan	2	36	21			-15	
91MN098	Mountain Lake Inlet	Upstream of CR 99, 2 mi W of Mountain Lake	Watonwan	3	0	0	21	28	0	7
90MN007	Minnesota River	Upstream of CSAH 212/59, 1 mi SW of Montevideo	Yellow Medicine	1	57	66			9	
90MN017	Hawk Creek	Upstream of 822nd Ave, 4 mi west of Sacred Heart	Yellow Medicine	1	32.5	37	53	68	4.5	15
90MN018	Minnesota River	Downstream of Hwy 10/21, in Renville County Park, 4.5 mi SW of Sacred Heart	Yellow Medicine	1	73	55			-18	
90MN019	Minnesota River	Adjacent to CR 81, 5 mi SW of Sacred Heart	Yellow Medicine	1	67	62			-5	
90MN020	Minnesota River	Adjacent to CR 15, 5 mi NW of Delhi	Yellow Medicine	1	67	42			-25	
91MN014	Spring Creek	Upstream of 470th St, 5 mi NW of Hanley Falls	Yellow Medicine	2	21	54	61	50	33	-11
91MN016	Judicial Ditch 18	Downstream of 180th Ave SW, 3mi NE of Prinsburg	Yellow Medicine	3	0	21			21	
91MN050	Trib. to Minnesota River	Upstream of 810th Ave, 2.5 mi SW of Sacred Heart	Yellow Medicine	3	0	0	0	0	0	0
91MN051	Camp Pope Creek	Upstream of River Road, 2.5 mi N of Redwood Falls	Yellow Medicine	3	34	64			30	
92MN052	Beaver Creek	Upstream of CR 2, in Beaver Falls	Yellow Medicine	2	45	71			26	

Appendix 2: MRAP Fish sampling locations and corresponding instream habitat scores. Negative changes are highlighted in red and positive changes are in green. Fish IBI Classes (1 = Southern Rivers; 2 = Southern Streams; 3 = Southern Headwaters; 7 = Low Gradient)

Site #	Stream Name	Fish IBI Class	1990-92 QHEI (MRAP)	2009-10 QHEI (MRAP)	2001 MSHA (MPCA)	2010 MSHA (MPCA)	20 Year Change	9 Year Change
90MN001	Pomme de Terre River	1	57	53.75			3.25	
90MN002	Lac qui Parle River, West Fork	3	58	65.3			-7.3	
90MN003	Lazarus Creek	3	43	56.3			-13.3	
90MN005	Ten Mile Creek	2	73	61.95			11.05	
90MN008	Signalness Creek	3	28	56.5	55	82.1	-28.5	-26.7
90MN010	Chippewa River, East Branch	2	63	76.4			-13.4	
90MN017	Hawk Creek	1	59	66.8	56	67	-7.8	-11.4
90MN053	Birch Coulee Creek	2	49	78			-29	
90MN058	Little Cottonwood River	2	58	61			-3	
90MN062	Plum Creek	2	66	69.8			-3.8	
90MN063	Highwater Creek	2	43	69.7	54	74.8	-26.7	-21.1
90MN069	Cottonwood River	1	64	71.2			-7.2	
90MN070	Minnesota River	1	48	64.1			-16.1	
90MN071	County Ditch #44	3	30	46.5			-16.5	
90MN073	Blue Earth River, West Branch	2	33	54.1			-21.1	
90MN077	Brush Creek	3	38	64			-26	
90MN081	Judicial Ditch #38	3	34.5	28.5			6	
90MN099	Watonwan River, South Fork	2	40	45.5	48	40.7	-5.5	7.52
90MN100	Watonwan River	1	64	70.25			-6.25	
90MN101	Blue Earth River	1	74	78.55			-4.55	
90MN105	LeSueur River	1	55	64.2			-9.2	
90MN108	Minnesota River	1	52	50.9			1.1	
90MN110	Rush River	1	55	68.1			-13.1	
90MN111	Buffalo Creek	3		76.2	67	72.9		-5.9
90MN113	Silver Creek	2	40	56			-16	
90MN114	Bevens Creek	2	74	60.25			13.75	

Site #	Stream Name	Fish IBI Class	1990-92 QHEI (MRAP)	2009-10 QHEI (MRAP)	2001 MSHA (MPCA)	2010 MSHA (MPCA)	20 Year Change	9 Year Change
90MN115	Minnesota River	1	67	42.1			24.9	
90MN116	Sand Creek	2	69	73.5			-4.5	
90MN117	Credit River	3	56.8	65.3	64	70.6	-8.5	-6.6
91MN013	Trib. to Dry Weather Creek	3	21	27			-6	
91MN014	Spring Creek	2	20	46	43	36.3	-26	6.75
91MN016	Judicial Ditch 18	3	29	34.5			-5.5	
91MN040	County Ditch 33	3	22	26			-4	
91MN050	Trib. to Minnesota River	3	49	55	62	54.9	-6	6.57
91MN051	Camp Pope Creek	3	76	52.9			23.1	
91MN054	County Ditch 106A trib	7	18	15.5			2.5	
91MN056	Little Cottonwood River	3	60	42	83	73	18	10.35
91MN057	Little Cottonwood River trib	3	28	21.5	37	30	6.5	7
91MN059	County Ditch 46A	3	19	38	39	35	-19	3.5
91MN060	Duck Lake outlet	3	39	56.6			-17.6	
91MN061	Rogers Creek	3	56	67.6	64	52	-11.6	12.25
91MN065	Trib. to Mound Creek	3	20	46.8	56	46.8	-26.8	8.7
91MN066	Mound Creek	3	73	41			32	
91MN067	Mound Creek	2	41	40	41	48.2	1	-6.75
91MN068	County Ditch 54	3	22	35			-13	
91MN080	County Ditch 26	3	27	24.5			2.5	
91MN086	Judicial Ditch 3	3	27	37			-10	
91MN089	County Ditch 60	3	35	52.5			-17.5	
91MN097	Judicial Ditch 1	2	60	64.45			-4.45	
91MN098	Mountain Lake Inlet	3	18	38	41	44	-20	-3.5
91MN102	Maple River	3	26	45			-19	
91MN103	County Ditch 5	7	18	12			6	
91MN104	Trib. to Big Cobb River	3	15	25			-10	
91MN109	County Ditch 43	3	13	29.5			-16.5	

Site #	Stream Name	Fish IBI Class	1990-92 QHEI (MRAP)	2009-10 QHEI (MRAP)	2001 MSHA (MPCA)	2010 MSHA (MPCA)	20 Year Change	9 Year Change
91MN112	Robert Creek	3	65	62.7	55	68.2	2.3	-13.5
92MN021	Redwood River	2	39	51.1			-12.1	
92MN022	Redwood River	2		51	52	56.6		-4.37
92MN023	Tyler Creek	2	30	48			-18	
92MN024	Tyler Creek	2	61	72.7			-11.7	
92MN025	Redwood River	2	55	72.6	63	72.7	-17.6	-10.2
92MN027	Coon Creek	2	52	43.75			8.25	
92MN028	Coon Creek	2	54	63.9			-9.9	
92MN030	Redwood River	2	66	57	52	73.8	9	-21.9
92MN031	Redwood River	2	34	38.4	45	48.3	-4.4	-3.8
92MN032	Redwood River	2	40	53			-13	
92MN033	Redwood River	1	33	35.9	50	54	-2.9	-4
92MN034	Three Mile Creek	3	30	51.2			-21.2	
92MN035	Three Mile Creek	2	32.5	51.9			-19.4	
92MN036	Three Mile Creek	2	32	48.5			-16.5	
92MN037	Redwood River	1	51	55.7			-4.7	
92MN038	Redwood River	1	35	33.2	38	45	1.8	-7
92MN039	Redwood River	1	31	38.5			-7.5	
92MN041	Redwood River	1	34	48.4	46	58.7	-14.4	-12.4
92MN042	Clear Creek	2	35	28.5			6.5	
92MN043	Clear Creek	2	63	63.9			-0.9	
92MN044	Redwood River	1	69	69.3	58	73.6	-0.3	-15.6
92MN045	Redwood River	1	68	73.65			-5.65	
92MN046	Ramsey Creek	2	27	35			-8	
92MN049	Redwood River	1	69	77.55	60	77.8	-8.55	-17.7
92MN064	Trib. to Mound Creek	3	62	65.15			-3.15	
92MN072	Blue Earth River, Middle Branch	2	35	48			-13	
92MN074	Coon Creek	2	38	47			-9	

Site #	Stream Name	Fish IBI Class	1990-92 QHEI (MRAP)	2009-10 QHEI (MRAP)	2001 MSHA (MPCA)	2010 MSHA (MPCA)	20 Year Change	9 Year Change
92MN075	Blue Earth River, East Branch	2	53	51			2	
92MN076	Foster Creek	2	26	36.5			-10.5	
92MN083	Center Creek	2	45	39.5	57	60.8	5.5	-3.65
92MN084	Center Creek	2	60	47.55	47	41.9	12.45	5.35
92MN085	Center Creek	2	29	54			-25	
92MN087	Elm Creek	2	61	54.6			6.4	
92MN096	Blue Earth River	1	52	53			-1	

Appendix 3: MBI score, 20 year change in MBI score, and the reflected ecological classification based on the 2009 MBI score. Changes highlighted in red indicate an increase in MBI score (negative response) with a resulting change in ecological condition, while changes in bold indicate a decrease in MBI score (positive change) with a resulting change in ecological condition. *Ecological condition does not reflect current TMDL status or assessment rating.*

Site Code	Water body Name	MBI Score (0 to 10)				Ecological Condition Based on MBI Score Based on Hilsenhoff (1988)		
		1990	1992	2009	20 Year Change	1990	1992	2009
ARL	High Island Creek	NS	4.58	6.27	1.69	-	Good	Fairly Poor
BFD	Trib. to Cobb River	NS	4.49	5.79	1.30	-	Good	Fairly Poor
CHP	Chippewa River	7.68	NS	5.80	-1.87	Very Poor	-	Fairly Poor
COT	Cottonwood River	5.19	NS	5.90	0.70	Fair	-	Fairly Poor
CPC	Camp Pope Creek	NS	6.20	6.22	0.02	-	Fairly Poor	Fairly Poor
CR13	Judicial Ditch 26	NS	5.50	8.62	3.12	-	Fair	Very Poor
CTD	Minnesota River	5.74	NS	4.83	-0.91	Fairly Poor	-	Good
DEL	Minnesota River	3.78	NS	8.39	4.61	Very Good	-	Very Poor
EBE	E. Branch Blue Earth River	NS	4.41	5.43	1.01	-	Good	Fair
FFX	County Ditch 106a	NS	6.72	8.53	1.81	-	Poor	Very Poor
FMT	Judicial Ditch 3	NS	6.69	7.44	0.74	-	Poor	Very Poor
FRO	County Ditch 44	NS	7.65	7.89	0.24	-	Very Poor	Very Poor
FTR	Minnesota River	3.84	NS	4.21	0.37	Very Good	-	Good
HEN	Minnesota River	7.85	NS	7.14	-0.71	Very Poor	-	Poor
HIS	High Island Creek	4.74	NS	5.85	1.12	Good	-	Fairly Poor
HWK	Hawk Creek	5.27	NS	5.55	0.28	Fair	-	Fair
JUD	Minnesota River	4.36	NS	8.68	4.32	Good	-	Very Poor
LQP	Minnesota River	7.08	NS	6.03	-1.06	Poor	-	Fairly Poor
MIN	County Ditch 37	NS	8.08	7.54	-0.55	-	Very Poor	Very Poor
MTL	Mountain Lake Ditch	NS	6.35	7.79	1.44	-	Fairly Poor	Very Poor
OML	Judicial Ditch 1	NS	4.52	8.29	3.77	-	Good	Very Poor
PEM	County Ditch 5	NS	6.70	9.00	2.30	-	Poor	Very Poor
ROS	Judicial Ditch 18	NS	6.98	9.29	2.30	-	Poor	Very Poor
RSH	Rush River	6.35	NS	6.17	-0.18	Poor	-	Fairly Poor
RWR	Redwood River	5.29	NS	4.53	-0.76	Fair	-	Good
STP	Minnesota River	3.40	NS	8.61	5.22	Excellent	-	Very Poor
UPS	Minnesota River	4.35	NS	8.86	4.51	Very Good	-	Very Poor
WEL	Maple River	NS	5.65	7.63	1.98	-	Fair	Very Poor
WIN1	Winnebago Ditch 1	NS	4.09	6.80	2.71	-	Very Good	Poor
WIN2	Winnebago Ditch 2	NS	3.46	5.63	2.17	-	Excellent	Fair
WTW	Watowan River	5.50	NS	5.57	0.07	Fair	-	Fair
YMR	Yellow Medicine River	5.82	NS	6.48	0.65	Fairly Poor	-	Fairly Poor

Appendix 4: IBI comparisons for sites sampled within the MRAP study area during 2001 and 2010. A 10 point change in IBI score represents a significant change. Negative changes are highlighted in red and positive changes are in bold. Aquatic life use status was designated based on 2010 IBI score, the bottom table provides a brief description of ALU status criteria.

Stream Name	MPCA Site #	Invert Class	2001 IBI	2010 IBI	IBI Change	ALU Status
Lac qui Parle River	90MN004	2	41	39	-2	Fair
Hawk Creek	90MN017	2	37	25	-13	Fair
High Water Creek	90MN063	5	50	50	0	Good
Little Cottonwood River	91MN056	5	35	33	-2	Fair
Little Cottonwood River Trib.	91MN057	7	12	28	16	Fair
County Ditch 46A	91MN059	7	11	10	-2	Poor
Mound Creek	91MN067	7	38	50	13	Fair
Redwood River	92MN022	5	29	14	-15	Poor
Redwood River	92MN025	5	49	17	-32	Poor
Redwood River	92MN030	5	36	24	-12	Fair
Redwood River	92MN033	7	42	42	0	Fair
Redwood River	92MN044	2	43	3	-41	Poor
Redwood River	92MN049	2	29	25	-4	Fair
Center Creek	92MN083	7	27	39	12	Fair
Center Creek	92MN084	5	22	22	0	Poor

ALU Status	Description
Good	Above upper confidence limit
Fair	Within threshold
Poor	Below lower confidence limit