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Cover Photograph: The top photo is from 2015 right after the concrete lining has been removed from the bottom of the detention basin at The Fargo Project and shows the first stages of stream restoration. The bottom photo is taken at the same spot as the top photo, but three years later (2018) and shows the state of the restored stream when macroinvertebrate sampling started. Photograph © Jack Norland.

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Macroinvertebrate Survey of a Restored Stream in a Dry Detention Basin

Kaylie Carver[1], Jack Norland[2], Donald Veverka[3], Alex Langevin[4], Carla Abel[5], and Christina Hargiss[6*]

Abstract – This study is the first to report on macroinvertebrate assemblages following restoration of a stream within a dry detention basin in Fargo, North Dakota after the concrete lining was removed. Excluding precipitation events, where discharge from the detention basin will pond for up to 36 hours, flows in detention basin outfalls are persistently low and intermittent. Therefore, it was unknown if fluctuating conditions due to ponding during precipitation events and subsequent low and intermittent streamflow would support macroinvertebrates. This study surveyed macroinvertebrates from 2018 to 2020, three to five years after stream restoration. Four locations were sampled three times each summer. Macroinvertebrate samples were collected using D-frame dip nets and then preserved in alcohol for subsequent identification. The Minnesota Hilsenhoff Family Biotic Index (HBI_MN) was calculated for all samples. The HBI_MN index for all samples ranged from 6.6 to 8.88, with an overall average of 7.78 indicative of disturbance-tolerant macroinvertebrates. Comparison to similar streams in the region finds HBI_MN values in this study consistent with values for the region. This study found restored streams in a detention basin can provide habitat for macroinvertebrates characteristic of the region.

Introduction

Increasing biodiversity and greening stormwater infrastructure are part of many urban management efforts (Levin and Mehring 2015, Larson et al. 2021). Detention basins are a common part of stormwater infrastructure (Maxted et al. 1999). Detention basins are excavated into the surrounding landscape, creating an area designed to store stormwater for a limited time as a way to control flooding downstream (Haberland et al. 2012, PEC 2012). Dry detention basins operate by allowing all water to drain within a day or two after a precipitation event, often via a concrete-lined channel that conveys the water while also minimizing erosion. Within the basin, high flows occur in the channel during and subsequent to precipitation events, but typically remain dry or have low to intermittent flows during dry weather. Wet detention (retention) basins are different, because they are designed to have a permanent pond or wetland in the bottom of the basin, providing a constant aquatic environment. One way to increase biodiversity in a dry detention basin is to remove the concrete lining and restore drainage systems (PEC 2012). Concrete linings provide limited habitat for aquatic organisms, removing them and restoring drainage with features such as pools and riffles will provide habitat and colonization sites. Basins can provide other functions such as introducing biodiversity and green space, often these come naturally and are not part of the original design features (Haberland et al. 2012).

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Studies on the effects of urban stream restoration on aquatic organisms has been reported in many developed landscapes (Lepczyk et al. 2017). What has not been studied or reported is information on aquatic organisms within restored streams in dry detention basins, after the concrete lining has been removed. There is a need for studies on restored streams in dry detention basins because the flow regime of a restored stream in a detention basin has the potential to be different from other urban restored streams. Other restored urban streams are subject to urban stream syndrome (Walsh et al. 2005; Booth et al. 2016). Flow regimes under the urban stream syndrome are characterized by flashy streamflow where stormwater runoff quickly reaches the urban stream causing a high peak in the hydrograph followed by stormwater quickly receding. The flashy flows will quickly flow out onto the floodplain, but just as fast recede from the floodplain (Booth et al. 2016). Dry detention basins have different flashy flow regimes. Within hours of a precipitation event, the restored stream will experience high peak flows and floodplain flooding, but instead of the water quickly receding, the dry detention basin is designed to start ponding. Once the basin fills, it will often empty within 24 to 36 hours and flow within the channel drops to ≤0.2 m^3/s (Huggins 2019). There is a need for studies on how ponding and altered flow regimes affects aquatic organisms.

Because there is a lack of studies on aquatic organisms with respect to restored streams in dry detention basins, we are reporting on an aquatic macroinvertebrates survey in a dry stormwater detention basin where the concrete lining of the stream channel was removed and restored to a natural streambed in 2015. The basin surveyed is part of an ecological naturalization art process to make a multifunctional green space called The Fargo Project (www.thefargoproject.com) within the city of Fargo, North Dakota. The Minnesota Hilsenhoff Biotic Index (HBI_MN) as modified by the Minnesota Pollution Control Agency (MPCA 2017) will be used to compare macroinvertebrate community composition to other streams in the region. The HBI_MN uses six disturbance scores to arrive at a tolerance value for each macroinvertebrate that integrates habitat disturbance with four water quality parameters. With the HBI_MN indicative of overall disturbance, the index allows for interpretations on how an aquatic macroinvertebrate community is responding to an overall set of disturbances. Comparisons with other streams in the region will establish if restoring streams in a dry detention basin can result in an aquatic environment suitable for macroinvertebrates as found in other streams, or whether the environment will only be suitable to tolerant macroinvertebrates.

Study Site and Methods

The Fargo Project is located in Fargo, North Dakota, USA (46°51’9.40”N, 96°51’9.98”W). The basin is 4.34 ha in size and was excavated 4.8 meters below grade (Fig. 1). The stormwater inlet on the east side of the basin has a catchment of 144 ha, while the inlet on the south side of the basin has an 18-ha catchment. Land use within the catchment is split among commercial uses for retail, lodging, office buildings, and high-density housing. The impervious areas within the catchment covers 42.3 % of total catchment area. There are no streams in the catchment basin and any flow into the basin comes through an underground stormwater system.

Trapezoid shaped concrete-lined channels, 3.5 m wide and 0.5 m high, with a gradual grade, were installed when the detention basin was built in the 1980s. These concrete-line channels did not allow for any water to pool and during dry periods the south-north channel was often dry while the east-west channel had flowing water that had a depth of 5 cm during dry times. The concrete-lined channels had no shade and there was no connection to ground water. Because of the lack of pools and shallow depth of concrete-lined channels there was limited aquatic habitat. As part of the detention basin retrofit, the concrete linings were removed in 2015. This removal was done with heavy equipment because of the 0.2 m-thick concrete liner. During the removal, all soil within 15 m of the channel was completely disturbed and used in the reshaping of the new channels. Removal was done during a dry period from August to October when flow in the concrete-lined channel was at its lowest, so remaining water in the channels was highly disturbed. The use of large equipment, disturbance of the surrounding soil, and creation of the new channels were such that the survival of aquatic organisms would have been limited.

The restored south-north channel was shaped into a trapezoid ranging from 1 m to 2.5 m in width using surrounding soil. The flow in this channel would be classified as intermittent. During stormwater events, flowing water has enough energy to scour out a great deal of standing vegetation in the deepest part of the channel, but not enough to cause the channel to move. During non-flooding periods there is limited flow from the stormwater inlet, and during dry periods there is no flow from the inlet. During periods with no stormwater flow, the channel has at least 20 cm of standing water and up to 50 cm due to high ground water levels. The channel has emergent vegetation, primarily *Typha ×glauca,* with other wetland species interspersed such as *Schoenoplectus tabernaemontani* (C.C. Gmel.) Palla (Softstem Bulrush). There are pockets of open water within the emergent wetland vegetation.

The east-west channel has a perennial flow of water. The stormwater inlet on the east side of the basin has a much larger catchment, and the stormwater system is often below

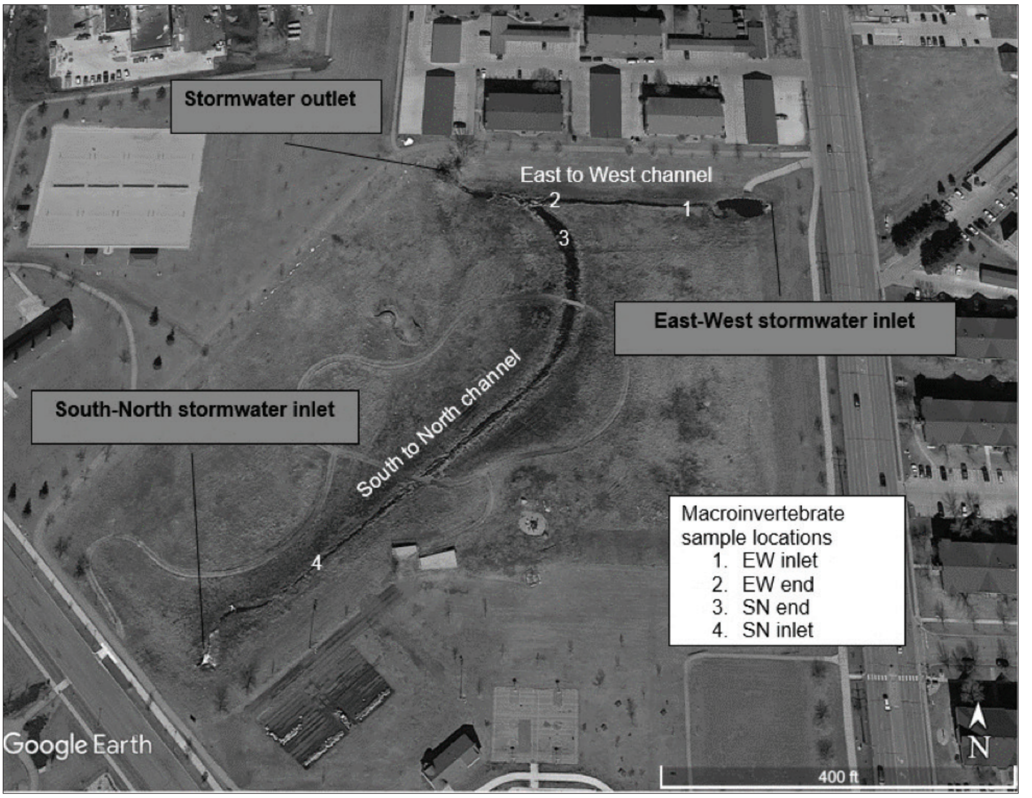

Figure 1. Location of the restored channels along with macroinvertebrate sample locations within The Fargo Project detention basin study site.

groundwater level and intercepts groundwater flows through openings in the pipe. These conditions result in perennial flow of 0.2 m^3/s even during extended dry periods (Huggins 2019). With recognition that perennial flow would be possible after the removal of the concrete lining, a natural channel design was implemented.

At the east inlet, a plunge pool (forebay) with a depth of 1.6 m was installed to reduce the energy of flows coming from the east inlet before moving into a new natural channel. This feature also allows for heavy sediment to be collected. After the plunge pool, a new natural channel design used induced meandering to create an open channel which would meander within a 4-m meander stream belt in a channel that averaged 1.8 m in width (Zeedyk 2009). Depth of the channel varies, with the deepest pools during extended dry periods being 0.5 m deep (Huggins 2019). To induce meandering, four induced meandering structures were built from the plunge pool west to the confluence of the two channels before the outlet. Two structures were made of rocks and the other two were riffles made with a combination of rocks and locally sourced willows. All structures have induced meandering which created pools below them, some with substantial overhanging banks. When the concrete lining was removed, the underlying 2-5 cm of rock the concrete was poured on was left, and this along with earth materials in the basin make up the channel bed. The channel has stabilized over the years with meanders slowly moving, but there is no longer any downcutting because of four induced meandering structures. There is little emergent vegetation in this channel as opposed to the south-north channel, which has a high coverage of emergent vegetation. During winter, the plunge pool will have unfrozen water, the south-north channel will freeze to the bottom, and the east-west channel will freeze mostly to the bottom. The riparian vegetation along both channels consists of *Spartina pectinate* Bosc ex Link (Prairie Cordgrass), *Salix interior* Rowlee (Sandbar Willow), and *Symphyotrichum lanceolatum* (Willd.) G.L. Nesom (White Panicle Aster) along with other riparian species, some of which are adapted to salinity. The riparian vegetation can overhang the east-west channel during the growing season creating shade and habitat for various aquatic organisms. During stormwater events, the riparian vegetation can often be flattened by high flows and commonly there is litter embedded in the vegetation.

During stormwater events, the basin contains up to a 3 m depth of ponded water (Huggins 2019). Flows coming from the east inlet can be 5 m^3/s and of sufficient energy to be channel forming flows for the east-west channel. Ponded water can start within several hours of a stormwater event depending on intensity of a precipitation event. It can last for as short as 5 hours or as long as 36 hours. Precipitation events that resulted in ponded water occurred 4–9 times a year with varying residence times for ponded water during the study. Four locations were selected for macroinvertebrate sampling; they were EW (East to West) inlet, EW end, SN (South to North) inlet, and SN end (Fig. 1). This sampling scheme resulted in two sampling locations on the south-north channel and two on the east-west channel. These two channels act differently and create unique conditions to which aquatic organisms may be adapted. The locations were sampled in July, August, and September in 2018, 2019, and 2020 for a total of nine samples at each sample location.

Macroinvertebrate sampling followed the Minnesota Pollution Control Agency protocol for stream monitoring sites (MPCA 2018). Sampling sites included three habitats, though only one or two occurred at each site: 1) hard bottom, 2) aquatic macrophytes, and 3) undercut banks/ overhanging. Sample locations EW inlet and EW end had hard bottoms and undercut banks/overhanging vegetation while SN end and SN inlet had aquatic macrophytes. At each sample site a D-frame dip net was used to collect macroinvertebrates. At hard bottom sites, the substrate was kicked in front of the net while sweeps were made into the undercut banks/overhanging vegetation. Sweeps were made at the aquatic macrophytes sites. The area sampled for each habitat was approximately 1.8 m^2. Samples were placed in sealed jars, preserved with alcohol, and stored in a refrigerator for later identification.

An introduction of fish was made to the plunge pool in fall of 2020. The majority of fish were *Culaea inconstans* Kirtland (Brook Stickleback), *Pimephales promelas* Rafinesque (Fathead Minnow), and *Umbra limi* Kirtland (Central Mudminnow). A collection of 100 wild caught individuals were added. The fish were added to increase the biodiversity of the restored stream since there is little possibility of fish colonizing from other areas using the stormwater system. The fish were surveyed in the fall of 2021 and 2022 using a standard minnow trap baited with bread placed in the plunge pool at the east to west inlet which has the deepest water (1.6 m).

All macroinvertebrates in each sample were identified to family level and genus when possible. Additionally, macroinvertebrate abundance for each family was recorded. The tolerance values for the macroinvertebrates were taken from the Minnesota tolerance values (MPCA 2017). The tolerance is derived from a combination of six disturbance variables; a disturbance score, habitat score, total phosphorus, total suspended solids, ammonium, and nitrate/nitrite. The values range from 0–10 with 0 values being intolerant of disturbance and 10 being tolerant of disturbance. These values were then utilized to calculate the HBI_MN. The HBI_MN was calculated for each location and date, where the number of macroinvertebrates in each family/genus was tallied and multiplied by the known tolerance value for that family/genus. After each family was tallied and multiplied, the products were all summed and then divided by the total number of macroinvertebrates in the sample (weighted average). A t-test using unequal variances was conducted with JMP® (Version 17. SAS Institute Inc., Cary, NC, 1989–2023) to test if the HBI_MN index values were different between the east-west and south-north channels over the course of the study.

Results and Discussion

A variety of macroinvertebrates were found in the restored streams within the detention basin (Table 1). One of the most common macroinvertebrates were scuds (Gammaridae). The tolerance value for this organism is 6.05, meaning they are not intolerant of disturbance, but are also not fully tolerant of disturbance (i.e., semi-pollution tolerant). Damselfly larvae (Coenagrionidae), both right-handed and left-handed snails (Lymnaeidae and Physidae), and water boatmen (Corixidae) were also common among samples. Tolerance values of these macroinvertebrates were higher than scuds, with left-handed snails having a tolerance value of 10. Total macroinvertebrate richness from all sample periods and locations was 12. Richness within a location and sample period ranged from 3 to 9, with an average from all locations and sample periods of 5.7 (SD = 1.2).

The HBI_MN Index values from each location and sample period ranged from a low of 6.6 to high of 8.88, with an overall average of 7.78 (SD = 0.52) (Table 2). The east-west channel had significantly lower HBI_MN values compared to the south-north channel (7.6 vs 8, SD = 0.52; $T = -2.45$, df = 34, P two tailed = 0.019). This lower value (i.e., more pollution-sensitive community) for the east-west channel is not surprising since the south-north channel is subject to low or stagnant flows with water depths of less than 0.5 m while the east-west channel has perennial flow. The south-north channel conditions would favor tolerant species like left-handed snails.

While there are no known studies of macroinvertebrates of restored streams in detention basins, there are reports and assessments of streams in Minnesota that utilized the same methods for this study. The restored stream in this study would classify as a Low Gradient, Prairie type stream (MPCA 2017). The range of HBI_MN values for the 5th and 95th percentile of surveyed streams of this type range from 5.8 to 8.8, respectively. The range of HBI_MN values for this study falls within the Minnesota Low Gradient stream type range, but one value met the 95th percentile value of 8.8. As a result, the restored stream is at the high or tolerant end of the HBI_MN scale for this type of stream. Thus, while macroinvertebrates in the restored steam in this study are tolerant of a variety of disturbances related to habitat and four water quality parameters, the HBI_MN index values are still within the range of similar streams types within the region. Therefore, restored streams in

Table 1. Family names of all macroinvertebrates found during the study and the number of times present at the four sample sites for the nine sampling periods. The HBI_MN tolerance values are shown. Species with tolerance values of N/A do not have tolerance values assigned.

	Presence out of nine sample periods				HBI_MN
Taxon Name (Class)	EW Inlet	EW End	SN Inlet	SN End	Tolerance Values
Chironomini (Insecta)	3	5	4	5	6
Aeshnidae (Inecta)	3	1	4	2	7.38
Gammaridae (Malacostraca)	9	9	9	9	6.05
Lymnaeidae (Gastropoda)	9	9	8	9	9.59
Physidae (Gastropoda)	7	7	8	4	10
Chironomidae (Insecta)	6	7	4	5	7.8
Coenagrionidae (Insecta)		3	4	4	9.73
Corixidae (Insecta)	7	9	7	7	8.86
Collembola (Collembola)			1		N/A
Culicidae (Insecta)	1				7.96
Tipulidae (Insecta)	2	1			5.8
Coleoptera (Insecta)*	4	2	3		N/A

*All individuals were flying adults.

Table 2. HBI_MN index values for each sample period and sample location

	Sample locations			
Sample period	EW Inlet	EW End	SN Inlet	SN End
2018 July	7.4	7.37	8.63	7.89
2018 August	8.29	7.46	8.74	7.99
2018 September	7.36	7.28	7.65	7.6
2019 July	6.6	8.02	7.67	8.29
2019 August	7.51	8.88	8.5	8.79
2019 September	7.11	7.39	7.51	7.96
2020 July	7.34	7.55	6.9	7.8
2020 August	7.66	7.84	8.26	7.88
2020 September	7.36	7.88	7.79	7.66
Average	7.4	7.74	7.96	7.98

this study provide habitat for macroinvertebrates though this habitat is subject to a variety of disturbances resulting in macroinvertebrate assemblages with a high tolerance to these disturbances. A high tolerance to disturbances can be found in similar stream types in the region. These restored streams should be considered capable of providing habitat which is representative of regional streams that are subject to disturbances present in other streams of the same type.

There are streams in Minnesota where a significant portion of the watershed is urbanized and subject to disturbances from urbanization. One such stream, Nine Mile Creek, is considered a disturbed natural stream. It is reported to have a long-term HBI average of 7.82 from 1997 to 2020 with a range of 6.68 to 8.8 (Barr 2021). Comparing the current project with Nine Mile Creek shows the HBI values are very similar with averages being close (7.78 vs 7.82). Plymouth Creek is an urbanized stream with parts of the stream being restored. The stream at this site had HBI values ranging from 4.3 to 6.5 from 1991 to 2016. In the same area, Bassett Creek was partially restored and had HBI values ranging from 4.5 to 7.6 (Bassett Creek Watershed Management Commission 2015). A similar urbanized stream, Minnehaha Creek, had an overall HBI range of 4.75 to 7 with a median value of 6 (Rufer 2014). Even though HBI index values for these restored streams were calculated differently from HBI_MN in relation to the stream in this study, these restored streams had a lower index value, except for Nine Mile Creek, which had a similar index value. Thus, most, but not all of these restored steams are characterized by having more intolerant macroinvertebrates than the current study.

Compared to other streams in Minnesota, the restored streams in this study had HBI_MN values at the tolerant end of the scale, but within the range exhibited by a Low Gradient, Prairie type stream and for some of the restored streams. Therefore, this one site shows that the different hydrology found in restored streams within a dry detention basin can provide habitat which can support aquatic organisms.

The continued survival of the introduced fish also supports the interpretation that the restored streams are providing adequate habitat to sustain aquatic species. Surveys two years following the introduction of native fish to the plunge pool found populations of *Pimephales promelas* with greater than 20 individuals. Thus, the habitat provided by the plunge pool even though small in size provided a deep pool aquatic habitat sufficient for fish survival enhancing the biodiversity of the site.

The use of induced meandering as implemented at this site is seen as an alternative way to create habitat for macroinvertebrates opposed to letting the channel self-organize or through a precisely designed channel. Using induced meandering reduces the risk that can come with allowing a channel to self-organized which could produce unwanted features, while the precisely designed channels can be expensive to install and runs the risk of it not performing to specifications. Using the fairly simple and low-cost features like rock riffles of induced meandering and allowing the stream to evolve is something we would advocate for in the future. Induced meandering allows for some control of how the stream channel will evolve while avoiding the risk or costs associated with other stream restoration methods.

The question which was not answered in the study was how macroinvertebrates came to be present in restored streams to the level similar to regional streams. Flying adults of macroinvertebrates are able to easily move into suitable habitats (Perron and Pick 2020). Other organisms which do not have such a dispersal mechanism would need to have persisted on-site during the concrete-lining removal or dispersed via the stormwater system. At this time, it is unknown what route non-flying aquatic organisms used to repopulate the restored stream. Nonetheless, it only took three years for the restored steams to have aquatic organisms similar to those found in regional steams. This study establishes that aquatic organisms can occupy a restored stream in a dry dentation basin and these results are possible in other highly urbanized, retrofitted dry detention basins with restored streams.

Summarizing, this study demonstrates that restored streams in a dry detention basin can provide habitat for aquatic organisms that are similar to other streams in the region. Aquatic organisms were able to populate the restored stream within the first three years after removing the concrete linings and this occurred in a heavily urbanized catchment where flow from underground stormwater systems are the only source of streamflow to the basin.

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