5 August 2011

Michelle LaForge
Au Sable Institute of Environmental Studies
710 High Street
Union Grove, WI 53182
262/994-4548
E-mail: Michelle.LaForge@my.wheaton.edu

A benchmark macroinvertebrate analysis of the Boardman River prior to dam removal

MICHELLE M. LAFORGE, Wheaton College, 501 College Avenue, Wheaton, IL 60187, USA

DAN IPPOLITO, Anderson University, 1100 East Fifth Street Anderson, IN 46012, USA

DAVE MAHAN, Au Sable Institute of Environmental Studies, 7526 Sunset Trail NE, Mancelona, MI 49659, USA

ROB KEYS, Cornerstone University, 1001 East Beltline Avenue Northeast, Grand Rapids, MI 49525, USA

ABSTACT In the late summer of 2012, the Brown Bridge Dam on the Boardman River in Traverse City, Michigan will be removed. The objective of this study is to provide a benchmark of current macroinvertebrate populations to aid in the restoration processes that will occur after dam removal. Three riffle sites were sampled using a stratified sampling technique. The macroinvertebrates collected were identified to genus level when practical and were subjected to Shannon's diversity index and Morisita's similarity index. In total, 2,662 macroinvertebrates were collected and identified. Analysis showed the site below the dam having the highest degree of species richness and diversity. When the sites were compared, the two upstream sites showed a high level of similarity, while the downstream site showed a high degree of differentiation.

KEY WORDS: : assessment, Biodiversity index, dam removal, marcroinvertebrate, Michigan, river

INTRODUCTION

The Brown Bridge Dam was erected on the Boardman River (Grand Traverse and Kalkaska Counties, Michigan) in 1921. In 2005, Traverse City Light and Power determined that it was no longer economically practical to generate hydroelectric power at this site and began plans for dam removal (CRA, 2011). With this dam removal, the Boardman River will be undergoing a massive restoration effort. However, there are currently no assessment records available that would provide the necessary baseline information to monitor and assess the success of the restoration. Our study aims to provide the foundation for future restoration efforts by offering a thorough assessment of macroinvertebrate populations, as macroinvertebrates provide a critical biological index of stream health because they integrate ecosystem stresses (Dodds 2002). For instance, the relative abundance of the taxon Ephemeroptera (mayflies), Tricoptera (caddisflies) and Plecoptera (stoneflies) in comparison to the rest of the macroinvertebrate assemblage is an indicator of stream health. These taxon are very intolerant of pollution and low levels of dissolved oxygen (IDNRDFW 2008, Bednarek and Hart 2005). Their preference for clean habitats has led to their use as biotic indices for stream water quality (Stark 1993; Dodds, 2002; Bednarek and Hart 2005; Hawkins 2006).

When sediment enters a fast-moving river system, the larger particles settle to the bottom and the fine sediment remains suspended in the water. This fine sediment is carried downstream where it will be deposited when the current velocity slows or when an obstruction is encountered that alters the stream function (Stanley and Doyle 2003). The Brown Bridge Dam, like all dams, has altered the movement of sediment within the system. When water approaches a dam, its sediment load is deposited behind the obstruction causing excess sedimentation to build up behind the dam.

The size of the substrate is an important physical factor in determining steam biota (Radwell and Brown 2007, Downes, et al 1998). Sediment rich regions are considered to be wastelands for invertebrates because there are no cracks or crevices for them to hide in or to shield themselves from the currents. There are also no large surface areas for algae to grow on to sustain the grazing species, like some Tricopterans. Thus, ideal habitats for macroinvertebrates are the riffle zones, characterized by shallow, swift moving currents and cobble, pebbles, gravel and other coarse substrates (Stark 1993). If the populations of macroinvertebrates upstream and downstream of the dam are quantitatively inventoried and compared, a higher level of biodiversity should be found downstream of the dam due to a decrease in fine sediment deposition. When the dam is removed, the degree of difference between populations should be minimized and become more similar in composition.

METHODS

Study Area

The Boardman River is a headwater stream in Grand Traverse and Kalkaska Counties, Michigan. The watershed of the Boardman is responsible for draining close to 74,000 ha of land and is rated as one of the top ten trout streams in Michigan, with 58 of 257 river kilometers designated as Blue Ribbon river sections (CRA 2011). At this location, three sampling sites were chosen to obtain a thorough macroinvertebrate assessment to evaluate how the Brown Bridge Dam has disrupted the river ecosystem and to create a benchmark for future restoration efforts (fig 1). Steve Largent, Grand Traverse Conservation District, directed us to riffles previously delineated for sampling by the Conservation Resource Alliance. Two sites were selected above the dam, one closer to the reservoir and the other further upstream, to investigate the influence of the dam on the biotic community.

The geographical coordinates for these sites were recorded using a Garmin GPSMap 60CSx GPS. Site A was located 4 km from the dam and 2.09 km from the mouth of the reservoir (N 44° 39.123'; W 085° 28.226'). Site B, between site A and the dam, was located 0.83 km downstream of Site A and 3.17 km upstream of the dam and 1.26 km from the mouth of the reservoir e(N 44° 38.928', W 085° 28.537'). Site C was located 0.40 km downstream of the Brown Bridge Dam (N 44° 38.563', W 085° 30.846').

Since the dam altered the way the river deposits sediment, it was assumed that the site closet to the dam would show diminished diversity as there would be more fine substrate present (Site B). To control for this, we added a second site further upstream at a riffle with very little sedimentation (Site A). Since the dam inhibited the sediment from flowing past it, only one riffle site was needed below the dam (Site C).

Stream Profile

Multiple abiotic measurements were taken of the Boardman River. During sampling session one, we only had equipment for recording air and water temperature. However, during sampling session two, we recorded air temperature, water temperature, dissolved oxygen, and surface velocity. Air temperature, water temperature and dissolved oxygen were recorded using a YSI 200 Ecosense DO probe. Surface velocity was measured using a 25-meter surveyors tape and a dense rubber ball. Three measurements were taken using this method and averaged to determine the approximate surface flow. The velocity readings were obtained from the middle of the river channel yielding maximum velocity results.

Sampling Methods and Macroinvertebrate Identification

We sampled riffles in a stratified manner along transects using a 0.5mm Surber Sampler with a 0.3 meter square sampling area. We used a three-pronged agitator to disturb the substrate for one minute in order to dislodge any macroinvertebrates present. The entire contents of the net – macroinvertebrates, macrophytes and substrates – were preserved in a 70% ethanol solution. At each locality, we conducted three stratified replicates along a transect that ran the width of the river.

The first sampling session occurred on 10 June 2011, a second session was conducted later on 29 June 2011, providing us with a total of 18 samples During the second sampling session, we took Surber samples from locations adjacent to our first samples to ensure similar collections and to avoid skewing our data by sampling the section previously disturbed.

In the lab, the contents of the individual collection jars were emptied into a tray and the macroinvertebrates were sorted from the macrophytes and substrate. Once the macroinvertebrates were sorted, we classified them down to the lowest possible taxonomic level using the aquatic invertebrate guides by Hilsenhoff (1975), Merrit and Cummings (2008) and Pennak (1978). In the event of damaged macroinvertebrates, only those with attached heads were identified and recorded to maintain consistency.

We analyzed the categorized and recorded taxons using Simpson's Index of Dominance and Diversity to show relative abundance of organisms present (Simpson 1949). Shannon's Diversity Index was also calculated in order to illustrate species richness and evenness between three sites (Shannon 1948). The communities above and below the dam were then compared for similarity using Morisita's Index of Community Similarity (Morisita 1959).

RESULTS

Our samples from three riffle sites along the Boardman River yielded biotic and abiotic results (Table 1). From these three localities, a total of 2,662 macroinvertebrates were collected and identified to the lowest practical taxonomic level (Appendix 1, Appendix 2). Using two diversity indices, Simpson's and Shannon's and analyzing the results using Morisita's index of similarity, the three sites were quantitatively compared to one another. Within the populations of all three sites, there were low levels of dominance and thus, high levels of diversity (Fig 2). However, the mean site composition of individuals was significantly different with site C consistently represented by the largest assemblage (Site A =154; Site B = 24, Site C = 1,152)(Fig 3). This is evidenced by the results of the Shannon Index (Fig 4). Site C, with a much higher individual count, has a fairly high species richness and evenness score (*H*=2.18). Whereas sites A and B scored identically lower than site C. These analyses are further supported by the results of Morisita's Index of Community Similarity (Fig 5). When the entire community composition is compared, sites A and B exhibit a high level of similarity. However, both have a high degree of differentiation from site C (A-B = 0.802; B-C = 0.234; A-C = 0.232). In this index, zero indicates no similarity while 1 indicates infinite or complete similarity.

Abiotic measurements (Table 1) indicate that the water below the dam is generally warmer than the upstream localities. This temperature discrepancy is highest during sampling session one where sites A and B measured 11.1C and site C measured 17.8C. The maximum flow velocity is highest at site A and declines along its downstream route, dropping below one meter per second below the dam.

DISCUSSION

When the populations of macroinvertebrates were quantitatively compared between both sites upstream of the Brown Bridge Dam with the downstream site, greater species richness was found below the dam at site C (*H* = 2.18). Site C also had the highest mean number of individuals present ($\bar{n}$ = 1,152). This can be explained by the presence of the dam, which disrupts the rivers sediment distribution capability (Stanley and Doyle 2003). The size of the substrate is an important physical factor for a macroinvertebrate habitat. Riffle zones, the primary habitat for this study, tend to exhibit the highest macroinvertebrate diversity when coarse substrates are present (Radwell and Brown 2007, Downes et al 1998, Stark 1993). Site C, which ranked the highest in terms of species richness and number of individuals present, had the highest quality riffle site because the dam pond accumulates the sedimentation. Site B, which was closest to the dam upstream, was the worst quality riffle and exhibited excess sedimentation. At this site, the fewest number of macroinvertebrates were recorded. However, it is important to note that high diversity is not necessarily indicative of stream health. The purpose of this study was to provide a benchmark inventory of the macroinvertebrate assemblages. To determine river health, this data needs to be further analyzed with attention paid to specific species present or absent.

The Boardman, which is ground water fed, is a cold-water stream year round. However, the water stored in the Brown Bridge Pond has allowed this water to undergo warming. Thus, the water directly downstream of the dam at site C is warmer than other sections of the river. As a result, the Tricopteran *Chimarra sp.*, which is normally found in warmer rivers, was recorded during both sampling sessions at this site.

Fluctuations in the data between sampling sessions may be attributed to a storm flow on the Boardman River just prior to sampling session two. During this sampling session, macroinvertebrates may have been washed downstream leading the data becoming more equalized than previously recorded from sampling session one. The presence of a terrestrial Coleopteran is further evidence of the inundation the river experienced from this disturbance (Appendix 2: Site A, Replicate 2).

The data collected during this study will be instrumental in providing a benchmark of the restoration of the stretch of river surrounding the Brown Bridge Dam upon its scheduled removal in the summer of 2012. After the disturbance of the dam removal levels out, and the fine sedimentation from the dam pond is flushed out of the system, an equalization of species richness should be observed between sites A, B and C.

ACKNOWLEDGEMENTS

I would like to thank R. Keys, D. Ippolito and D. Mahan for their continued mentorship, Adam’s Chapter of Trout Unlimited for their financial contributions, S. Largent and the Conservation Resource Alliance for their support and for aiding in site selection, N. Sather and S. Wunder for their assistance in the field, A. Janofski for creating my site map, and my fellow research interns, J. Boone and W. Miller for their support.

LITERATURE CITED

Bednarek, A.T., and D.D. Hart. 2005. Modifying dam operations to restore rivers: ecological responses to Tennessee River dam mitigation. Ecological Applications 15 (3): 997-1008.

Conservation Resource Alliance (CRA). 2011. The Boardman: a river reborn. http://www.theboardman.org/, 8 July 2011.

Dodds, W.K. 2002. Freshwater ecology concept and environmental applications. Academic Press, San Diego, CA.

Downes B.J., P.S. Lake, E.S. Schreiber, and A. Glaister. 1998. Habitat structure and regulation of local species diversity in a stony, upland stream, Ecological Monographs 68 (2): 237-257.

Hawkins, C.P. 2006. Quantifying biological integrity by taxonomic completeness: its utility in regional and global assessments, Ecological Applications 16 (4): 1277-1294.

Hilsenhoff, W.L. 1975. Aquatic insects of Wisconsin. Revised Edition ed. Department of Entomology, University of Wisconsin Madison, WI.

Indiana Department of Natural Resources Division of Fish and Wildlife (IDNRDFW). 2008. Hoosier riverwatch: volunteer stream monitoring training manual. Indianapolis, Indiana, USA.

Merritt, R.W., K.W. Cummins, and M.B. Berg. 2008. An introduction to the aquatic insects of North America. Iowa: Kendall/Hunt Publishing Company.

Morisita, M. 1959. Measuring of interspecific association and similarity between communities. Memoirs Faculty Kyushu University, Series E 3:65-80.

Pennak, R.W. 1978. Fresh-water invertebrates of the United States. 2nd ed. New York: John Wiley & Sons Inc.

Radwell A. J., and A.V. Brown. 2008. Benthic meiofauna assemblage structure of headwater streams: density and distribution of taxa relative to substrate size, Aquatic Ecology 42: 405-414.

Simpson, E.H. 1949. Measurement of diversity. Natura163: 688.

Shannon, C.E. 1948. A mathematical theory of communication. Bell System Technical Journal 27: 379–423 and 623–656.

Stanley, E.H., and M.W. Doyle. 2003. Trading off: The ecological effects of dam removal, Frontiers in Ecology and the Environment 1 (1): 15-21.

Stark, J.D. 1993. Performance of the macroinvertebrate community index: Effects of sampling method, sample replication, water depth, current velocity, and substratum on index values, New Zealand Journal of Marine and Freshwater Research 27: 463-478.

Table 1. Abiotic measurements of the Boardman River taken at each of the three sample sites (A, B, C).

Measurements		Site A	Site B	Site C
Dissolved Oxygen (DO)		101.5%	100.9%	97%
		10.0mg/L	10.0mg/L	9.4mg/L
Air Temperature*	Sampling 1	12.8C	12.2C	15C
	Sampling 2	19.8C	20.8C	16.8C
Water Temperature*	Sampling 1	11.1C	11.1C	17.8C
	Sampling 2	16.1C	15.7C	17.1C
Surface Velocity		1.24m/sec	1.06m/sec	0.94m/sec

*****Only air and water temperatures were recorded during sampling session one.

FIGURE LEGEND

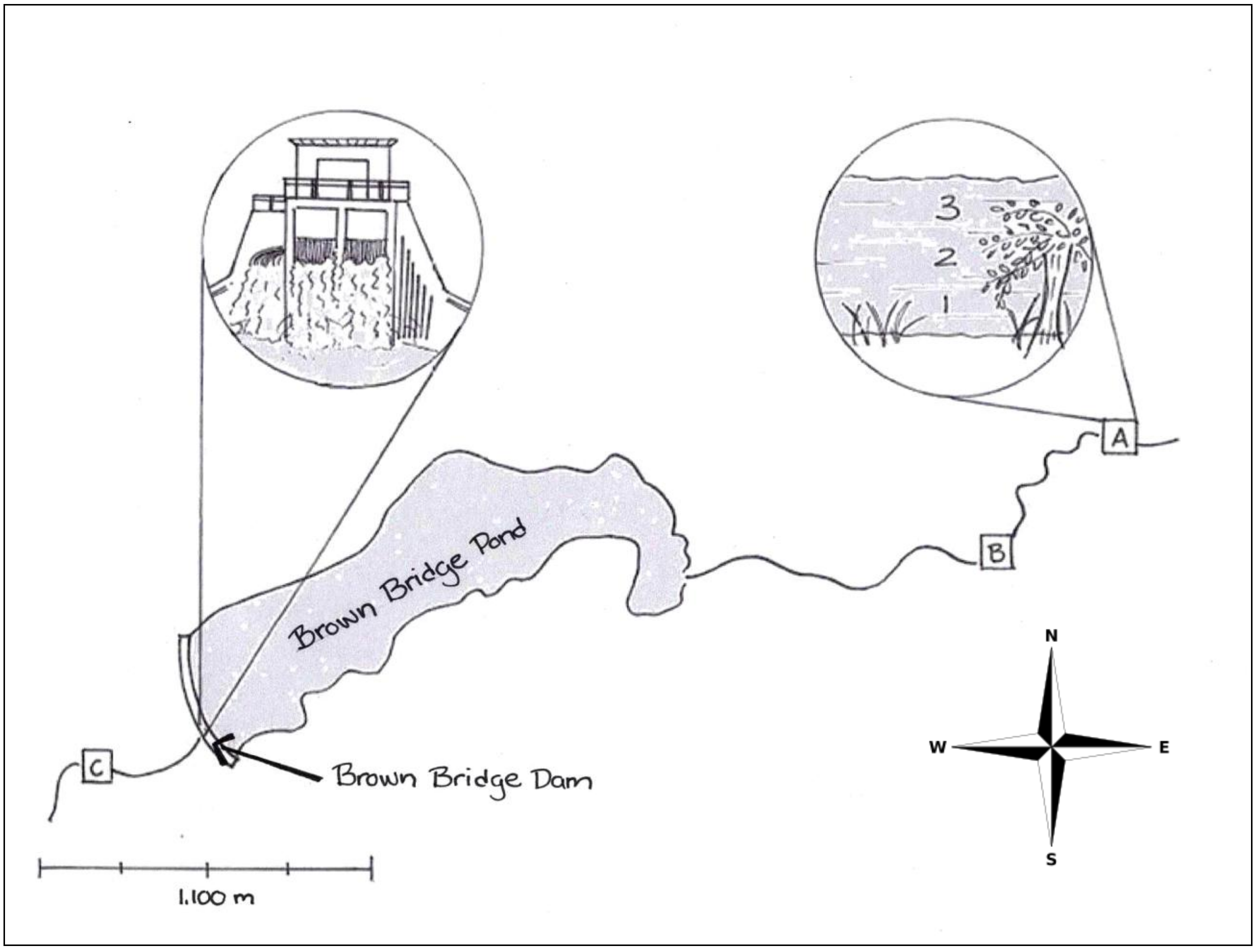
Figure 1. The three sites (A, B and C) sampled along the Boardman River which runs through Grand Traverse and Kalkaska Counties, Michigan. At each site, three stratified sampled were conducted. Illustration by Ashley Janofski

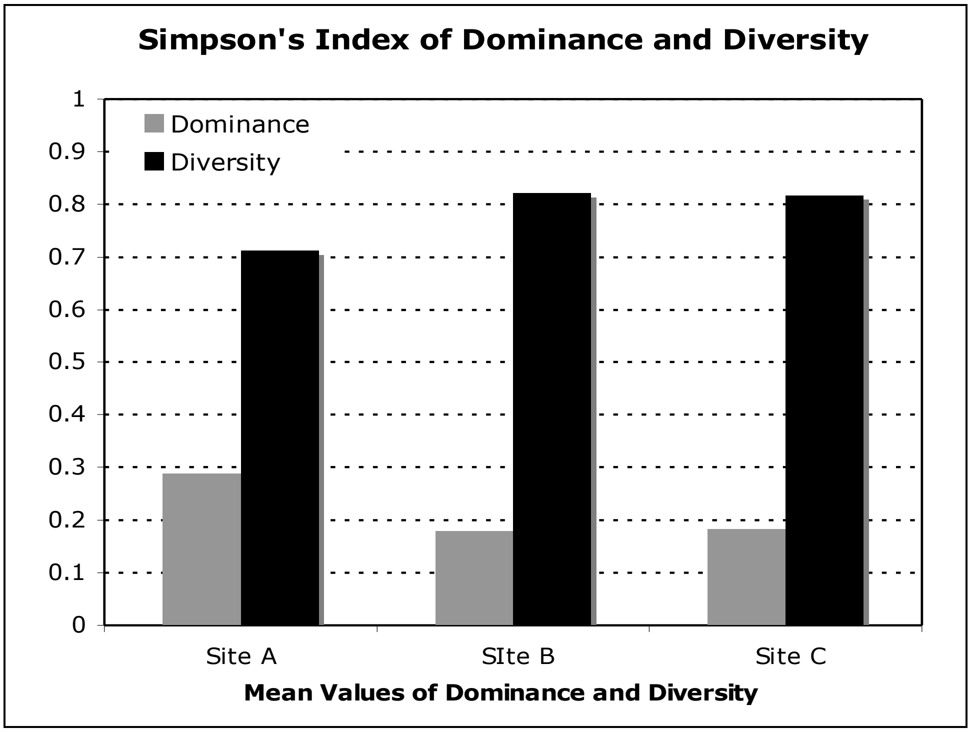
Fig 2. Site comparison using Simpson's Index of Dominance and Diversity, which is based on a scale of 0 to 1, with 0 being no dominance/ diversity and 1 being infinite or complete dominance/ diversity.

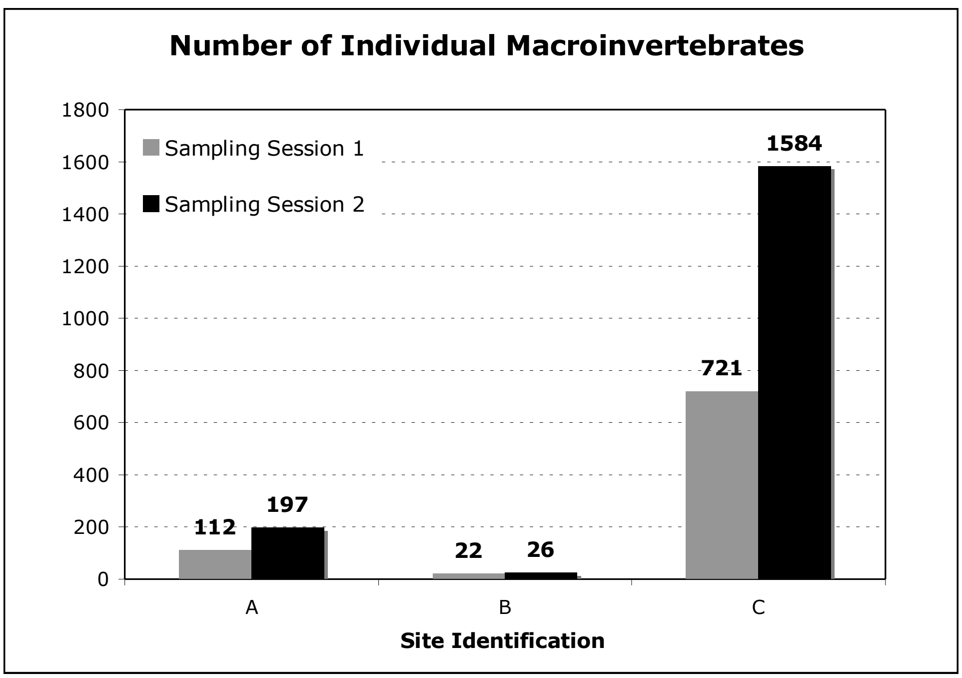
Fig 3. The total accumulation of macroinvertebrates collected, distributed according to site and sampling session.

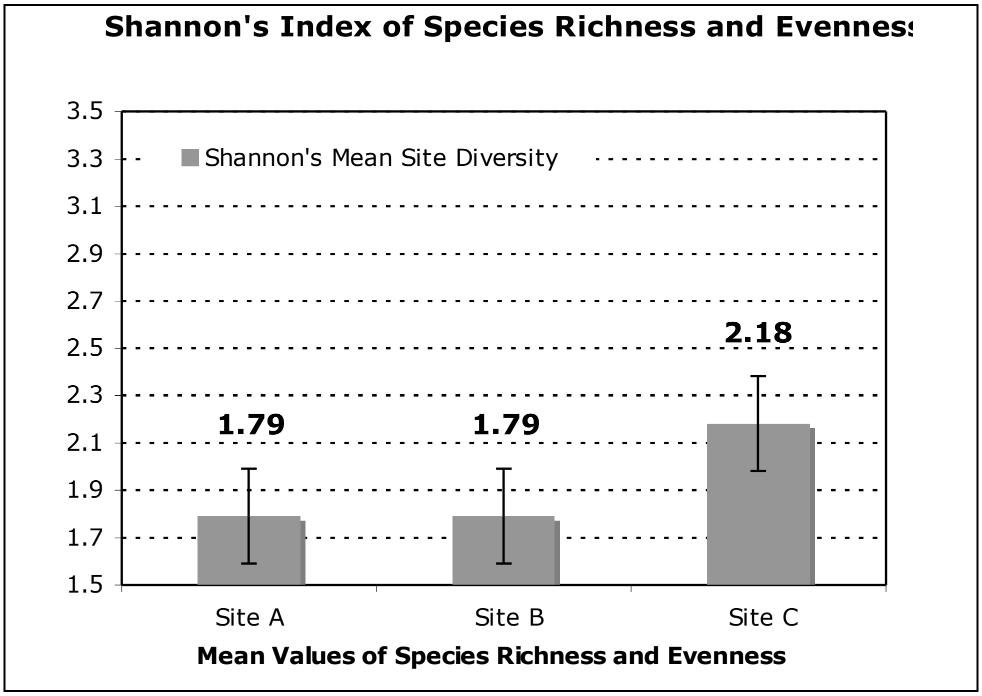
Fig 4. Site comparison using Shannon's Diversity Index which is based on a scale of 1.5 to 3.5, with 1.5 being low species richness and evenness and 3.5 being high species richness and evenness.

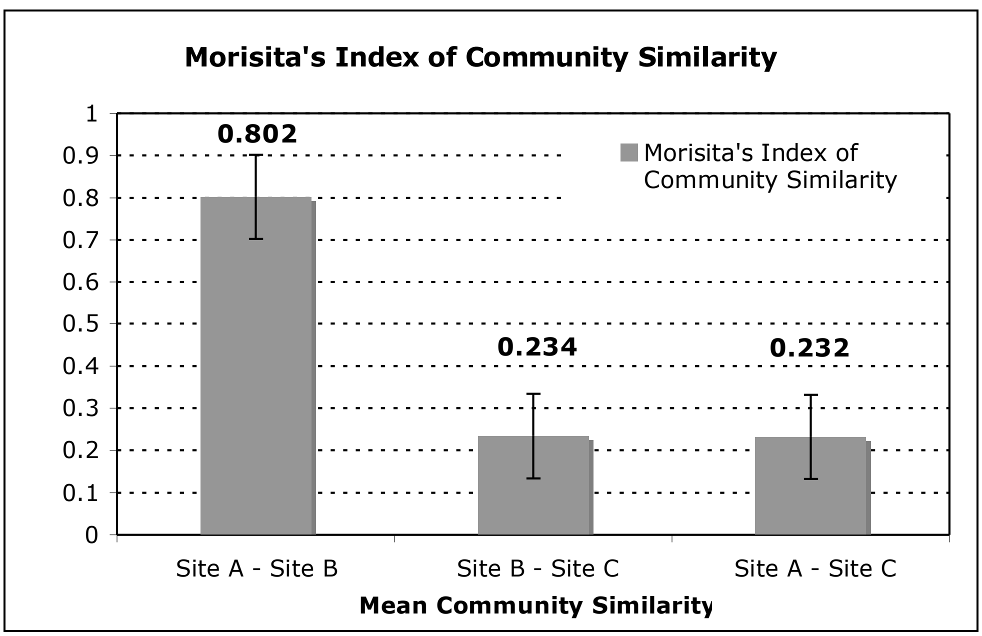
Fig 5. Site comparison using Morisita's Index of Community Similarity which is based on a scale of 0 to 1, with 0 being no similarity and 1 being complete similarity.


3
2
1
A
B
Brown Bridge Pond
C
Brown Bridge Dam
N
W
E
S
1,100 m


Simpson's Index of Dominance and Diversity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Dominance
Diversity
Site A
SIte B
Site C
Mean Values of Dominance and Diversity


Number of Individual Macroinvertebrates
1800
1600
1400
1200
1000
800
600
400
200
0
Sampling Session 1
Sampling Session 2
112
197
22
26
721
1584
A
B
C
Site Identification


Shannon's Index of Species Richness and Evennes
3.5
3.3
3.1
2.9
2.7
2.5
2.3
2.1
1.9
1.7
1.5
Shannon's Mean Site Diversity
1.79
1.79
2.18
Site A
Site B
Site C
Mean Values of Species Richness and Evenness


Morisita's Index of Community Similarity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.802
0.234
0.232
Morisita's Index of Community Similarity
Site A - Site B
Site B - Site C
Site A - Site C
Mean Community Similarity

Appendix 1a. Macroinvertebrates belonging to class Insecta collected from the Boardman River during sampling session 1 (10 June 2011). (L) = Larva (e), (P) = Pupa (e). Total number of individual invertebrates: 432

		Site A			Site B			Site C		
Order - Family	***Genus sp.***	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**
Coleoptera										
Elmidae	*Narpus sp.*	-	7	3	2	-	3	16	34	25
Diptera										
Athericidae	*Atherix sp.*	4	2	1	-	-	-	-	-	-
Chironomidae	Unknown (L)	-	-	1	-	-	3	14	17	13
	Unknown (P)	-	-	2	-	-	-	4	1	-
Empididae	*Chelifera sp.*	1	-	-	-	-	-	-	-	-
Simuliidae	*Simulium sp.*	1	1	1	-	-	-	-	59	41
Ephemeroptera										
Baetidae	*Baetis sp.*	1	-	1	-	-	-	29	3	-
Ephemerellidae	*Drunella sp.*	-	2	6	1	-	-	-	2	-
	Ephemerella sp.	50	8	13	8	1	-	-	3	-
	Eurylophella sp.	-	-	-	-	1	-	-	-	-
Heptageniidae	*Heptagenia sp.*	-	-	-	-	-	-	-	2	6
Odonata										
Gomphidae	*Erpetogomphus sp.*	1	-	-	-	-	-	-	-	-
Unknown	Unknown	-	-	-	-	-	-	-	-	1
Plecoptera										
Perlodidae	*Isoperla sp.*	2	-	-	-	-	-	-	-	-
Trichoptera										
Apataniidae	*Apatania sp.*	-	-	-	-	-	-	2	7	-
Brachcentridae	*Brachycentrus sp.*	-	-	-	-	-	-	-	3	1
	Micrasema sp.	-	-	-	-	-	1	2	-	-
Helicopsychidae	*Helicopsyche sp.*	-	-	-	-	-	-	1	2	-
Hydropsychidae	*Hydropsyche sp.*	2	-	-	-	-	-	4	3	2
Lepidostomatidae	*Lepidostoma sp.*	-	-	-	-	-	-	-	1	-
Philopotamidae	*Chimarra sp.*	-	-	-	-	-	-	-	4	-

Appendix 1b. Macroinvertebrates belonging to classes other than Insecta collected from the Boardman River during sampling session 1 (10 June 2011). Total number of individual invertebrates: 423

			Site A			Site B			Site C		
Class (Subclass)	**Order**	**Family**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**
Clitellata (Oligochaeta)	Unknown	Unknown	-	-	-	-	-	-	8	24	-
Arachnida	Trombidiformes	Hydrachnidae	-	1	-	-	-	-	-	9	-
Malacostraca	Amphipoda	Gammaridae	-	-	-	-	-	-	-	2	14
	Isopoda	Asellidae	-	-	-	-	-	-	67	107	126
Bivalva	Veneroida	Dreissenidae	-	-	-	-	-	-	-	10	12
	Unknown	Unknown	-	1	-	-	-	1	1	-	-
Gastropoda*	Unknown	Unknown 1	-	-	-	-	-	-	3	2	-
	Unknown	Unknown 2	-	-	-	-	-	-	-	1	-
Turbellaria	Tricladida	Planariidae	-	-	-	-	1	-	22	11	-

*Gastropoda consisted of right-handed snails (Unknown 1) and flat-spiral snails (Unknown 2).

Appendix 2a. Macroinvertebrates belonging to class Insecta collected from the Boardman River during sampling session 2 (29 June 2011). (L) = Larva (e), (P) = Pupa (e). Total number of individual invertebrates: 888

	Site A	**Site B**	**Site C**

*Leptohyphidae formerly classified as Tricorythidae.

Order - Family	***Genus sp.***	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**
Coleoptera										
Elmidae	*Narpus sp.*	18	3	26	1	-	-	27	59	44
Unknown	Unknown Terrestrial	-	1	-	-	-	-	-	-	-
Diptera										
Athericidae	*Atherix sp.*	7	1	2	-	-	-	-	1	4
Chironomidae	Unknown (L)	18	17	18	1	6	-	12	141	73
	Unknown (P)	3	2	4	-	-	-	-	-	12
Empididae	*Chelifera sp.*	7	4	1	-	-	-	-	-	-
Simuliidae	*Simulium sp.*	3	1	2	1	-	-	6	176	4
	Unknown (P)	-	-	-	-	-	-	-	37	-
Tipulidae	*Antocha sp.*	-	-	-	-	-	-	-	2	-
Unknown	Unknown	1	-	-	-	-	-	-	-	-
Ephemeroptera										
Baetidae	*Baetis sp.*	-	1	-	-	-	-	4	-	-
Ephemerellidae	*Drunella sp.*	3	1	18	-	-	-	-	-	1
	Ephemerella sp.	11	7	3	-	1	4	-	-	-
	Eurylophella sp.	-	-	-	-	-	-	-	-	2
Heptageniidae	*Heptagenia sp.*	-	-	-	-	-	-	-	-	2
Leptohyphidae*	Unknown (L)	4	1	-	-	-	-	-	-	-
Odonata										
Gomphidae	*Erpetogomphus sp.*	1	-	-	-	-	-	-	-	1
Plecoptera										
Perlodidae	*Isoperla sp.*	-	-	-	1	-	-	-	-	-
Trichoptera										
Apataniidae	*Apatania sp.*	-	-	-	-	-	-	4	2	3
Brachcentridae	*Brachycentrus sp.*	-	-	-	-	1	4	-	-	-
	Micrasema sp.	2	-	-	-	-	4	-	1	2
Helicopsychidae	*Helicopsyche sp.*	-	-	-	-	-	-	-	5	2
Hydropsychidae	*Hydropsyche sp.*	-	-	-	-	-	-	1	15	3
	Unknown (P)	-	-	-	-	-	-	-	2	-
Lepidostomatidae	Unknown (P)	-	-	-	-	-	-	-	3	-
Leptoceridae	Unknown (P)	-	-	-	-	-	-	-	10	3
Philopotamidae	*Chimarra sp.*	-	-	-	-	-	-	2	4	-
	Unknown (P)	-	-	-	-	-	-	-	1	-
Polycentropodidae	Unknown (P)	-	-	-	-	-	-	-	1	-
Unknown	Unknown	-	-	-	-	1	-	-	-	-

Appendix 2b. Macroinvertebrates belonging to classes other than Insecta collected from the Boardman River during sampling session 2 (29 June 2011). Total number of individual invertebrates: 919

			Site A			Site B			Site C		
Class (Subclass)	**Order**	**Family**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**	**R1**	**R2**	**R3**
Clitellata (Oligochaeta)	Unknown	Unknown	-	-	-	-	-	-	4	12	3
Arachnida	Trombidiformes	Hydrachnidae	4	1	-	-	1	-	-	8	17
Malacostraca	Amphipoda	Gammaridae	-	-	-	-	-	-	4	21	5
	Isopoda	Asellidae	-	-	-	-	-	-	80	322	50
Bivalva	Veneroida	Dreissenidae	-	-	-	-	-	-	1	46	73
	Unknown	Unknown	-	-	-	-	-	-	-	1	2
Gastropoda*	Unknown	Unknown 1	-	-	-	-	-	-	2	30	1
	Unknown	Unknown 2	-	-	-	-	-	-	-	-	1
Turbellaria	Tricladida	Planariidae	-	-	1	-	-	-	11	155	63

*Gastropoda consisted of right-handed snails (Unknown 1) and flat-spiral snails (Unknown 2).