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Effects of Keystone Pond drawdown on riffle macroinvertebrate communities

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ABSTRACT In 2007, Keystone Pond, the reservoir behind the Boardman Dam on the Boardman River in Grand Traverse County, Michigan was drawn down due to safety concerns about the integrity of the dam. The objective of this study was to determine whether the newly formed channel (Lone Pine) has returned to a natural state as compared to an upstream control site (Shumsky Road) using macroinvertebrate indicators. Since the drawdown five years ago, macroinvertebrates have been annually collected and identified to the lowest practical taxonomic level. The data were analyzed using Simpson's Index of Diversity and Sørensen's Quotient of Similarity. We determined that while the newly formed riffle channel had recovered to a more natural state, the macroinvertebrate communities are still changing and not yet comparable to the upstream control site.

KEY WORDS: Boardman River, biodiversity, dam removal, EPT/C, Michigan

INTRODUCTION

Dam removal projects have increased in recent years (Stanley and Doyle 2003; Cumming 2004; Orr et al. 2008; Hansen and Hayes 2011). As dams reach the end of their life expectancy, they must be either brought up to code for re-licensure or removed. Such retrofitting of small hydroelectric dams is typically not cost effective as they do not produce enough hydropower to outweigh costs of the retrofit (CRA 2012). Dam life expectancy averages 50 years, and by 2020, about 80% of the 2.5 million dams in the US will have exceeded this age (Hansen and Hayes 2011). As such, a number of small hydroelectric dams are now up for removal (Stanley and Doyle 2003).

Dams alter natural flow patterns, disrupt transport of sediment, change water temperature downstream, and can hinder natural migration patterns of fishes (Cheng et al. 1998; Cumming 2004; Principe 2010; Colas et al. 2011). Although the negative effects of dams are well documented, long-term effects of dam removal are not as well understood. The purpose of this study was to better understand how macroinvertebrate communities would change in response to river channel redevelopment following the drawdown of the Keystone Pond.

Water quality is often assessed using macroinvertebrates as bioindicators. They constitute the lowest link of aquatic food webs. Because they are relatively immobile, macroinvertebrate communities are excellent indicators of current water quality. This is because they are subject to any stresses in the water and cannot immediately recover from disturbances (Stark 1993). Creating an index of water quality to compare multiple sites is accomplished by analyzing the macroinvertebrates present (Bushaw-Newton et al. 2002; Orr et al. 2008). For example, the ratio of pollution intolerant and tolerant genera can be used to quantify water quality. Ephemeroptera, Plecoptera, and Trichoptera orders are considered intolerant of pollution, while some members of the family Chironomidae are considered tolerant of pollution (Hoosier Riverwatch 2012). Stream recovery can then be assessed by comparing EPT/C ratios for consecutive years (Hansen and Hayes 2011).

The Boardman Dam (N44° 41’ 53.53”, W85° 37’ 14.85”; Fig. 1) is one of four dams along the Boardman River. It is a hydroelectric dam constructed in 1894 and rebuilt in 1930. In 2005, Traverse City Light and Power decommissioned the Boardman Dam and two others because the cost of repairs and re-licensure was not economically feasible. In 1961, the deteriorating Keystone Dam along the Boardman River washed out (CRA 2008). In efforts to prevent this from happening to the Boardman Dam, Keystone Pond (the reservoir created by the Boardman Dam), was lowered by 5.18 m in 2007 in preparation for the structural removal of the dam. Since the drawdown, the newly formed channel has been undergoing natural restoration. It was hypothesized that the restoration of this stretch of river to a more natural, cold-water, free-flowing river would improve the ecological health of the Lone Pine site as indicated by the macroinvertebrate community (Hansen and Hayes 2011). The Boardman River restoration project is currently the largest dam removal project in Michigan, as well as the largest wetland restoration project in the Great Lakes Basin (CRA 2012).

After a large disturbance, benthic macroinvertebrate communities have been shown to recover and resemble natural upstream communities (Laasonen et al. 1998; Maloney et al. 2008). Following the drawdown of Keystone Pond, natural restoration of the river channel should assist in recovery of the macroinvertebrate communities following the disturbance. By comparing benthic macroinvertebrate communities at the site undergoing natural restoration (Lone Pine) with an upstream control site (Shumsky Road) over five consecutive years, we should observe the recovery of the disturbed site causing it to closely resemble the control site.

MATERIALS AND METHODS

Study site

The Boardman River begins in the Mahan Swamp (Kalkaska County, Michigan) and flows into the west arm of Grand Traverse Bay of Lake Michigan (Grand Traverse County, Michigan) (Fig. 1). It is a 5th order river comprised of 258 km of river and tributary streams encompassing a 743 km^2 watershed. Approximately 58 km of the Boardman River is classified as a Blue Ribbon trout stream and has been rated one of the top ten trout fishing streams in Michigan (CRA 2012).

On 9 June 2012, we sampled two riffle sites in the river upstream from Traverse City, Michigan: Shumsky Road (N44° 39' 2.91", W85° 35' 27.40") and Lone Pine (N44° 41' 7.02", W84° 37' 35.71"). The Shumsky Road site was located 11.12 km upstream from the Boardman Dam (9.95 km upstream from the current mouth of Keystone Pond) and represented the control site. Our experimental site, Lone Pine, was located in the newly formed channel resulting from the drawdown of Keystone Pond in 2007. It was 2.10 km upstream from the Boardman Dam (0.93 km upstream from the current mouth of Keystone Pond).

Riffle sampling

At the two sites, six replicate samples along a riffle transect were selected using a stratified sampling method. These shallow, swift moving areas provided excellent gravel and cobble habitat for macroinvertebrates. Sampling only riffle sites while avoiding macrophytes and fine sediment areas reduced variation in macroinvertebrate communities associated with differences in microhabitats (Heino et al. 2004). We collected macroinvertebrates using a 500 μm mesh Surber Sampler with a 0.3 m^2 sampling area. The sampling area was agitated for one minute to suspend any macroinvertebrates from the sediments into the water column where the current washed them into the collection net. This process was repeated for each of the six replicates at both sites. All of the contents from the collection net were emptied into a sample jar and preserved in 70% ethanol solution prior to analysis. We identified macroinvertebrates to the lowest practical taxonomic level using aquatic invertebrate keys by Merritt et al. (2008) and Pennak (1979). In the case of damaged specimens, we only counted organisms with intact heads for standardization. Families were then assigned pollution tolerance values (0-10) as described by Bouchard (2004), Landcare Research (2012), Connecticut Department of Environmental Protection (2012) and West Virginia Save Our Streams (2012) for statistical analysis.

We collected additional field data including air temperature (°C), water temperature (°C), maximum surface velocity (m/s), and replicate site depth (m), and transect width (m) to better understand the abiotic state of the river. We recorded temperature using a mercury thermometer; mean maximum surface velocity (N=3) as 10 m travel time of a floating glass sample vial (30 mL; 3.5 cm x 7 cm); depth at each replicate site using a standard meter stick and river width with a surveyor’s tape.

Statistical Analysis

Sampling macroinvertebrate communities has occurred annually in June since 2008 at these two sites (D Mahan and J Louwsma, unpublished data 2008; unreferenced; D Mahan and N Sather, unpublished data 2011; unreferenced). During these previous field seasons three replicates were collected per site on two sampling sessions, and data was combined between the sampling sessions yielding a total of six replicates per site. Data were re-analyzed at the genus level rather than the morphospecies level to maintain consistency between field seasons, resulting in updated calculations from originally reported results. In 2012, we collected six replicate samples per site during one sampling session. This was to eliminate variability in communities due to variable between sampling sessions such as insect hatches or storms.

Data were analyzed using Simpson's Index of Diversity to determine the relative abundance of organisms at the two sites (Simpson 1949). To measure percent similarity between sites and test for overlap of organisms, we calculated Sørensen's Quotient of Similarity (*QS*) (Sørensen 1948). A common method for determining water quality is by calculating the relative proportion of mayflies, stoneflies, and caddisflies to midges. Ephemeroptera (mayflies), Plecopteran (stoneflies), and Trichopteran (caddisflies) orders are sensitive to pollution, while many members of the Chironomidae (midges) family are tolerant of pollution. Therefore, EPT/C ratios were utilized to calculate an index of water quality. (Klemm et al. 2003). A high EPT/C ratio is indicative of high water quality, whereas a low EPT/C ratio is indicative of poor water quality. In order to further analyze potential differences between sites, we analyzed data based on families in order to account for different tolerances to pollution within genera. We compared the number of sensitive individuals (tolerance value $\leq$ 3) to the number of tolerant individuals (tolerance value $\geq$ 7).

RESULTS

2008 Field Season

Shumsky Road and Lone Pine sites were first sampled on 12 June 2008 and 26 June 2008 (Appendix 1; Appendix 2). Data between sampling dates were pooled yielding 551 individuals from Shumsky Road and 20 individuals from Lone Pine (Fig. 2). Simpson's Index of Diversity (*D*) was higher at Shumsky Road than at Lone Pine (*D*=0.8265; 0.6316, respectively) (Fig. 3).

EPT/C was significantly higher at Shumsky Road (4.08) than Lone Pine (0.33) ($\chi^2 = 24.433$; *d.f.* = 1; $P < 0.01$) (Fig. 4). Similarly, the difference between number of sensitive and tolerant families present in each community also showed a significant difference between sites ($\chi2$ = 18.308; *d.f.* = 1; $P < 0.01$). Shumsky Road and Lone Pine showed little similarity between sites (*QS* = 21.74%; Fig. 5). The dominant families were Helicopsychidae (33.21%) and Chironomidae (60.00%) for Shumsky Road and Lone Pine sites respectively.

2009 Field Season

Shumsky Road and Lone Pine were sampled on 12 June 2009 and 28 June 2009 (Appendix 1; Appendix 3). Shumsky Road yielded 84 individuals while Lone Pine yielded 45 individuals (Fig. 2). Both sites had high levels of diversity (*D* = 0.8930; 0.9010, respectively) (Fig. 3). Although not significant, the EPT/C ratio was higher at Shumsky Road (3.57) than at Lone Pine (2.33) ($\chi^2 = 0.604$; *d.f.* = 1; $P = 0.44$) (Fig. 4). Sensitive and tolerant families also did not differ between sites ($\chi^2 = 0.034$; *d.f.* = 1; $P = 0.85$). The presence of different genera between sites was nearly similar (*QS* = 48.78%) (Fig. 5). At Shumsky Road, the most abundant families were Elimidae and Tabanidae (each 26.19%) while at Lone Pine, Chironomidae was most abundant (22.67%).

2010 Field Season

Shumsky Road and Lone Pine were sampled on 10 June 2010 and 25 June 2010 (Appendix 1; Appendix 4). From Shumsky Road, 267 individual macroinvertebrates were collected while 414 individuals were collected from Lone Pine (Fig. 2). Shumsky Road was slightly more diverse than Lone Pine (*D* = 0.7405; 0.6980, respectively) (Fig. 3). EPT/C ratio was higher at Shumsky Road (1.34) than Lone Pine (0.90), however this difference was not significant (χ^2 = 3.381; *d.f.* = 1; *P* = 0.07) (Fig. 4). Sensitive and tolerant families did, however, significantly differ between sites (χ^2 = 30.331; *d.f.* = 1; *P* < 0.01). Shumsky Road and Lone Pine sites shared a moderate level of simlarity (*QS* = 63.64%; Fig. 5). The most abundant families were Elimidae (46.44%) and Chironomidae (47.67%) at Shumsky Road and Lone Pine sites, respectively.

2011 Field Season

Shumsky Road and Lone Pine were sampled on 9 June 2011 and 28 June 2011 (Appendix 1; Appendix 5). Shumsky Road yielded 258 individual macroinvertebrates. 102 individuals were collected from Lone Pine (Fig. 2). *D* was slightly higher at Shumsky Road (0.7928; 0.7430, respectively) (Fig. 3). EPT/C ratio was much higher at Shumsky Road than Lone Pine (8.80; 0.88, respectively; Fig. 4) and was significantly different (χ^2 = 41.425; *d.f.* = 1; P < 0.01). Similarly, the sensitive and tolerant families present also significantly differed between sites (χ^2 = 46.848; *d.f.* = 1; P < 0.01). *QS* showed a 64.71% similarity between Shumsky Road and Lone Pine (Fig. 5). Again, the most abundant families were Elimidae (45.28%) and Chironomidae (47.06%) at Shumsky Road and Lone Pine sites, respectively.

2012 Field Season

Shumsky Road and Lone Pine were sampled on one date rather than two separate sampling sessions to eliminate variance in data due to hatching insects or storms. On 9 June 2012, we collected both abiotic measurements in order to better understand the current condition on the river (Table 1). Air and water temperature were fairly similar at Shumsky and Lone Pine (Shumsky: 23°C , 19°C ; Lone Pine: 26°C , 18°C). Since the river was narrower at Lone Pine than Shumsky (18.4 m; 12.7 m), we observed a slightly faster current at the Lone Pine site (1.19

±0.04 m/s; 1.11 ±0.06 m/s, respectively). We also observed that the appearance of the bottom material appeared to be less stable at the Lone Pine site.

We collected 340 individuals from Shumsky Road and 27 individuals from Lone Pine. Shumsky Road was slightly less diverse than Lone Pine (*D* = 0.8622; 0.9202, respectively) (Fig. 3). Although not significant, EPT/C ratio was higher at Shumsky Road (7.64) than Lone Pine (3.40) (χ^2 = 1.159; *d.f.* = 1; P = 0.28) (Fig. 4). Sensitive and tolerant individuals present at each site were also not statistically different (χ^2 = 0.011; *d.f.* = 1; *P* = 0.92). *QS* showed 53.66% similarity between families present at each of the sites (Fig. 5). The most abundant family at Shumsky Road was Elimidae (30.88%) while Helicopsychidae was most abundant at Lone Pine (23.08%).

DISCUSSION

Our results generally support a recovering test site (Lone Pine) in the newly formed channel of the Boardman River in comparison to the upstream control site (Shumsky road) following the drawdown of Keystone Pond. We have observed a moderate degree of similarity (*QS* $\geq$ 50%) between the test site and control site in 2010, 2011 and 2012 (Fig. 5), which is evidence of a riffle channel that has recovered to a more natural state, however a total recovery has not yet been observed. The recovery may have come to a plateau. This may be due to the instability of the river bottom as down-cutting is still occurring at the test site. We would expect the sites to continue to become more similar in future years of this study as restoration continues and the river bottom is stabilized (Laasonen et al. 1998). It is also possible that the test site will never recover to resemble the control site as the river is a natural system and there may be other factors limiting a full recovery.

A recovery to a more natural state is also evident in the relatively high diversity of riffle macroinvertebrate communities as observed over the five years following the drawdown. The diversity of the test site closely resembled that of the upstream control site following the first year of the study (Fig. 3). We observed that the diversity was actually higher at the test site in the 2012 field season than at the control site. It must be noted, however, that the test site contained markedly fewer individuals than the control site (Fig. 2). Such a large difference in individual organisms would argue for an incomplete recovery at Lone Pine.

The EPT/C ratio has been fairly variable at both the test site and the control site (Fig. 4). Generally, the EPT/C richness value has become more similar since the first year of the study. Significant statistical differences in EPT/C ratios occurred in 2008 and 2011. One potential factor in the large difference observed in 2011 was a bankfull discharge following a large storm just prior to the second sampling session (D Mahan and N Sather, unpublished data 2011; unreferenced). This storm may have notably affected results of another macroinvertebrate analysis of the Boardman River further upstream during the same sampling sessions (D Mahan and M LaForge, unpublished data 2011; unreferenced); downstream sites showed more similarity in composition to upstream control sites as individuals from upstream were potentially displaced downstream.

In order to more accurately assess water quality, we compared the percent of sensitive and tolerant genera present at each site by year (Fig. 6). In each of the five years of this study, Shumsky Road had more sensitive genera than tolerant. Lone Pine, however, varied, having more sensitive genera some years, and more tolerant genera other years. This variance is again likely due to the instability of the river bottom.

The most abundant families at the control site have consistently been indicators of moderate to good water quality (Helicopsychidae, Elimidae, and Tabanidae) (Merritt et al. 2008). The most abundant family at the recovering site has typically been Chironomidae, organisms typically indicative of poor water quality (Merritt et al. 2008). However, in 2012, Helicopsychidae became the dominant family at the test site, further supporting increased water quality in the recovering riffle channel.

Our data supports our alternate hypothesis that the Boardman River has undergone significant recovery to a more natural state since the 2007 drawdown of Keystone Pond. The data, however, do not yet show that the newly formed riffle channel supports a macroinvertebrate community resembling the upstream control site. We have observed that, relative to previous years, the down-cutting of the river channel had diminished and the river bottom has appeared to become more stable. As the channel continues to stabilize, we expect the macroinvertebrate community to also stabilize at our test site. We recommend that this study be continued throughout the dam removal and stream recovery process to further support this analysis.

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Appendix 1. Macroinvertebrates from classes other than Insecta collected from the Shumsky Road and Lone Pine sites along the Boardman River, Grand Traverse County, Michigan, USA in 2008 (12 June; 26 June), 2009 (12 June; 28 June), 2010 (10 June; 25 June), 2011 (9 June; 28 June), and 2012 (9 June). Total number of non-insect individuals collected from Shumsky Road (Sh.) and Lone Pine(LP) sites, respectively: 2008 (48; 2), 2009 (3; 3), 2010 (3; 4), 2011 (2; 0), 2012 (30; 0).

			2008		**2009**		**2010**		**2011**		**2012**	
Class (Subclass)	**Order**	**Family**	**Sh.**	**LP**	**Sh.**	**LP**	**Sh.**	**LP**	**Sh.**	**LP**	**Sh.**	**LP**
Arachnida	Trombidiformes	Hydrachnidae	1	1	0	0	0	0	0	0	9	0
Malacostraca	Amphipoda	Gammaridae	0	0	0	0	0	1	0	0	0	0
Clitellata (Oligochaeta)	Unknown	Unknown	45	0	2	1	3	2	2	0	15	0
Clitella (Hirudinae)	Unknown	Unknown	0	0	0	1	0	1	0	0	0	0
Gastropoda	Lymnaeidae	Unknown	1	0	0	0	0	0	0	0	0	0
	Physidae	Unknown	0	0	1	1	0	0	0	0	0	0
	Valvatidae	Unknown	1	1	0	0	0	0	0	0	0	0
Pelecypoda	Sphaeriidae	Unknown	1	0	0	0	0	0	0	0	0	0
Gordioidea	Gordiidae	Gordius	0	0	0	0	0	0	0	0	6	0

Appendix 2. Macroinvertebrates from Class Insecta collected from the Shumsky Road and Lone Pine sites along the Boardman River, Grand Traverse County, Michigan, USA on 12 June 2008 and 26 June 2008. Individuals with unknown genera note pupae (P) form. Total number of insect individuals: Shumsky Road, 502; Lone Pine, 18.

Order	**Family**	***Genus* sp.**	**Shumsky Road**	**Lone Pine**
Coleoptera	Elimidae	*Optioservus* sp.	57	0
Diptera	Athericidae	*Atherix* sp.	23	0
		Unknown sp. (P)	1	0
	Chironomidae	Unknown sp.	79	12
	Empididae	Unknown sp. (P)	1	0
	Simuliidae	*Ectemma* sp.	3	0
		Prosimulium sp.	2	0
		Simulium sp.	4	0
		Unknown sp.	2[a]	2
	Tabanidae	*Tabanus* sp.	2	0
		Unknown sp. (P)	2	0
	Tipulidae	*Antocha* sp.	2	0
		Prionocera sp.	1	0
Ephemeroptera	Ephemerellidae	*Drunella* sp.	85	0
		Ephemerella sp.	1	0
		Seretella sp.	6	0
	Heptageniidae	*Epeorus* sp.	1	0
		Stenonema sp.	1	0
	Oligoneuriidae	*Isonychia* sp.	1	0
Megaloptera	Corydalidae	*Nigronia* sp.	1	0
Plecoptera	Perlidae	*Acroneuria* sp.	2	0
Trichoptera	Brachycentridae	*Brachycentrus* sp.	6	1
		Micrasema sp.	7	0
	Glossosomatidae	*Glossosoma* sp.	1	0
	Helicopsychidae	*Helicopsyche* sp.	183	3
	Hydropsychidae	*Cheumatopsyche* sp.	3	0
		Hydropsyche sp.	1	0
	Hydroptillidae	*Neotrichia* sp.	2	0
		Unknown sp. (P)	1	0
	Lepidostomatidae	*Lepidostoma* sp.	3	0
	Leptoceridae	*Leptocerus* sp.	1	0
		Oecetis sp.	13	0
		Setodes sp.	1	0
	Limnephelidae	Unknown sp. (P)	1	0
	Philopotamidae	Unknown sp. (P)	2	0

[a] Individuals originally classified *Eusimulium* sp., however after further investigation, it was discovered that this particular genus does not inhabit this region.

Appendix 3. Macroinvertebrates from Class Insecta collected from the Shumsky Road and Lone Pine sites along the Boardman River, Grand Traverse County, Michigan, USA on 12 June 2009 and 28 June 2009. Individuals with unknown genera note larvae (L) or pupae (P) form. Total number of insect individuals: Shumsky Road, 81; Lone Pine, 42.

Order	Family	*Genus* sp.	Shumsky Road	Lone Pine
Coleoptera	Elimidae	*Microcylloepus*	11	0
		Optioservus sp.	9	0
		Stenelmis sp.	2	1
		Unknown sp. (L)	0	1
	Athericidae	*Atherix* sp.	1[a]	0
Diptera	Chironomidae	Unknown sp.	7	12
	Empididae	*Hemerodromia* sp.	1	0
	Simuliidae	*Simulium* sp.	3	0
	Tabanidae	*Athericiae* sp.	1	0
		Unknown sp. (P)	22	0
Ephemeroptera	Baetidae	*Baetis* sp.	4	2
		Unknown sp.	1	2
	Ephemerellidae	*Atenella* sp.	1	0
		Drunella sp.	6	2
		Unknown sp.	1	0
	Heptageniidae	*Heptagenia* sp.	1	0
	Unknown	Unknown sp.	3	0
Plecoptera	Perlodidae	*Isogenoides* sp.	0	1
Trichoptera	Brachycentridae	*Brachycentrus* sp.	2	3
		Micrasema sp.	1	5
	Helicopsychidae	*Helicopsyche* sp.	0	3
	Hydropsychidae	*Cheumatopsyche* sp.	0	1
		Deplectrona sp.	0	1
	Hydroptillidae	*Ochrotichia* sp.	0	3
	Lepidostomatidae	*Lepidostoma* sp.	1	5
	Leptoceridae	*Mystacides* sp.	1	0
	Polycentropodidae	*Polycentropus* sp.	1	0
	Rhyacophilidae	*Rhyacophila* sp.	1	0
	Unknown	Unknown sp.	1	0

[a] Previously classified as Tabanidae *Athericiae* sp., however was reclassified as Athericidae *Atherix* sp. as it was likely a misspelling in the original reported data.

Appendix 4. Macroinvertebrates from Class Insecta collected from the Shumsky Road and Lone Pine sites along the Boardman River, Grand Traverse County, Michigan, USA on 10 June 2010 and 25 June 2010. Individuals with unknown genera note larvae (L) or pupae (P) form. Total number of insect individuals: Shumsky Road, 264; Lone Pine, 410.

Order	**Family**	***Genus* sp.**	**Shumsky Road**	**Lone Pine**
Coleoptera	Elimidae	*Optioservus* sp.	124	28
		Unknown sp. (L)	0	1
Diptera	Athericidae	*Atherix* sp.	5	2
	Chironomidae	Unknown sp.	47	194
	Empididae	Unknown sp. (P)	5	0
	Simuliidae	*Simulium* sp.	3	5
		Twinnia sp.	1	0
		Unknown sp. (P)	1	1
	Tipulidae	Unknown sp. (P)	0	1
	Unknown	Unknown sp. (L)	15	4
Ephemeroptera	Baetidae	*Baetis* sp.	12	113
	Ephemerellidae	*Drunella* sp.	15	25
		Serratella sp.	2	2
		Unknown sp.	0	1
	Heptageniidae	*Stenonema* sp.	0	1
	Unknown	Unknown sp.	0	2
Plecoptera	Unknown	Unknown sp.	0	1
Trichoptera	Brachycentridae	*Brachycentrus* sp.	3	3
		Micrasema sp.	20	10
	Glossosomatidae	*Glossosoma* sp.	0	2
		Unknown sp. (P)	2	0
	Helicopsychidae	*Helicopsyche* sp.	4	2
	Hydropsychidae	*Cheumatopsyche* sp.	0	2
	Lepidostomatidae	*Lepidostoma* sp.	4	7
	Leptoceridae	*Ceraclea* sp.	1	0
	Philopotamidae	*Dolophilodes* sp.	0	1
		Wormaldia sp.	0	2

Appendix 5. Macroinvertebrates from Class Insecta collected from the Shumsky Road and Lone Pine sites along the Boardman River, Grand Traverse County, Michigan, USA on 9 June 2011 and 28 June 2011. Individuals with unknown genera note larvae (L) or pupae (P) form. Total number of insect individuals: Shumsky Road, 256; Lone Pine, 102.

Order	**Family**	***Genus* sp.**	**Shumsky Road**	**Lone Pine**
Coleoptera	Elimidae	*Optioservus* sp.	108	9
		Stenelmis sp.	7	0
Diptera	Athericidae	*Atherix* sp.	3	1
	Chironomidae	Unknown sp.	10	48
	Simuliidae	*Prosimulium* sp.	14	0
		Simulium sp.	15	1
		Twinnia sp.	6	1
	Tipulidae	*Antocha* sp.	3	0
	Unknown	Unknown sp. (L)	1	0
Ephemeroptera	Baetidae	*Baetis* sp.	5	13
	Ephemerellidae	*Drunella* sp.	17	10
		Ephemerella sp.	2	1
		Serratella sp.	1	0
	Heptageniidae	*Heptagenia* sp.	0	1
Trichoptera	Brachycentridae	*Brachycentrus* sp.	2	3
		Micrasema sp.	26	8
	Helicopsychidae	*Helicopsyche* sp.	26	0
	Hydropsychidae	*Cheumatopsyche* sp.	3	0
	Lepidostomatidae	*Lepidostoma* sp.	3	3
	Odontoceridae	*Psilotreta* sp.	1	0
	Philopotamidae	*Wormaldia* sp.	0	3
	Unknown	Unknown sp.	3[a]	0

[a] One individual was originally classified Odontoceridae *Namayia* sp., however after further investigation, it was discovered that this particular genus does not inhabit this region.

Appendix 6. Macroinvertebrates from Class Insecta collected from the Shumsky Road and Lone Pine sites along the Boardman River, Grand Traverse County, Michigan, USA on 9 June 2012. Individuals with unknown genera note larvae (L) or pupae (P) form. Total number of insect individuals: Shumsky Road, 310; Lone Pine, 27.

Order	**Family**	**Genus sp.**	**Shumsky Road**	**Lone Pine**
Coleoptera	Elimidae	*Optioservus* sp.	105	0
Diptera	Athericidae	*Atherix* sp.	29	0
	Ceratopogonidae	*Dasyhelea* sp.	0	1
	Chironomidae	Unknown sp.	14	5
	Empididae	*Hemerodromia* sp.	5	1
		Unknown sp. (P)	1	0
	Simuliidae	*Simulium* sp.	15	2
		Unknown sp. (P)	32	0
	Thaumaleidae	Unknown sp. (L)	2	0
	Tipulidae	*Antocha* sp.	0	1
Ephemeroptera	Baetidae	*Baetis* sp.	1	1
	Ephemerellidae	*Drunella* sp.	41	1
		Ephemerella sp.	2	0
		Serratella sp.	3	1
	Heptageniidae	*Maccaffertium* sp.	2	0
	Unknown	Unknown sp.	0	1
Plecoptera	Perlodidae	*Isoperla* sp.	0	1
Trichoptera	Brachycentridae	*Brachycentrus* sp.	9	1
		Micrasema sp.	16	2
	Glossosomatidae	Unknown sp. (P)	3	1
	Helicopsychidae	*Helicopsyche* sp.	22	6
	Hydropotilidae	*Hydroptila* sp.	1	0
	Lepidostomatidae	*Lepidostoma* sp.	2	2
	Leptoceridae	*Oecetis* sp.	1	0
		Unknown sp. (L)	1	0
	Philopotamidae	Unknown sp. (P)	2	0
	Rhyacophilidae	*Rhyacophila* sp.	1	0

Table 1. Abiotic measurements recorded at two sample sites along the Boardman River, Grand Traverse County, Michigan, USA on 9 June 2012.

Measurements	**Shumsky Road**	**Lone Pine**
Air Temperature (°C)	23	26
Water Temperature (°C)	19	18
Mean Maximum Surface Velocity (m/s)	1.11 (±0.04)	1.19 (±0.06)
River Width (m)	18.4	12.7

FIGURE LEGEND

Figure 1. Map of Boardman River, Grand Traverse and Kalkaska Counties, Michigan, USA. Macroinvertebrates collected from Shumsky Road and Lone Pine sites annually June of 2008-2012. Data sources include ArcGIS Online and the Michigan Center for Geographic Information.

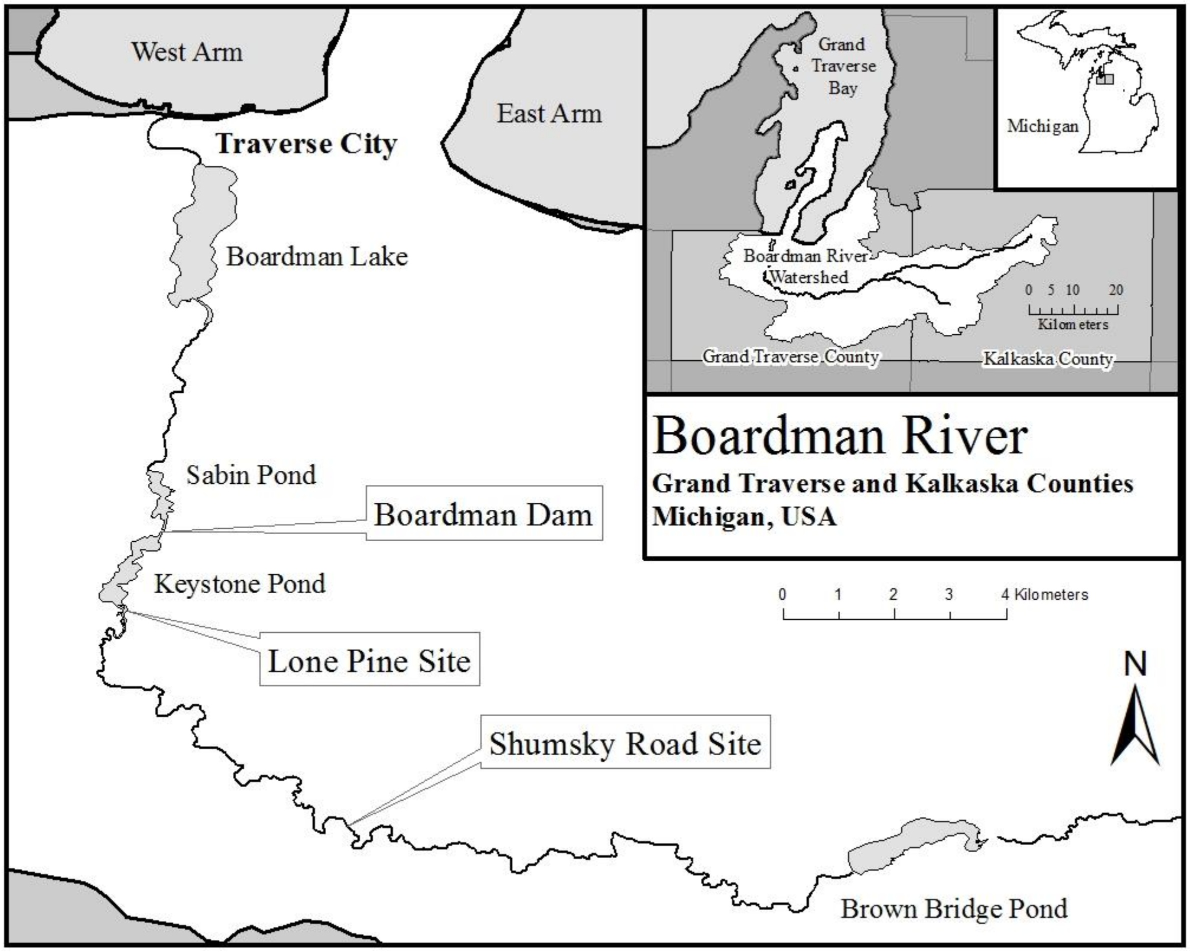
Figure 2. Comparison of total individual macroinvertebrates collected from Shumsky Road and Lone Pine sites, Boardman River, Grand Traverse County, Michigan, USA. Macroinvertebrates collected annually in June of 2008-2012.

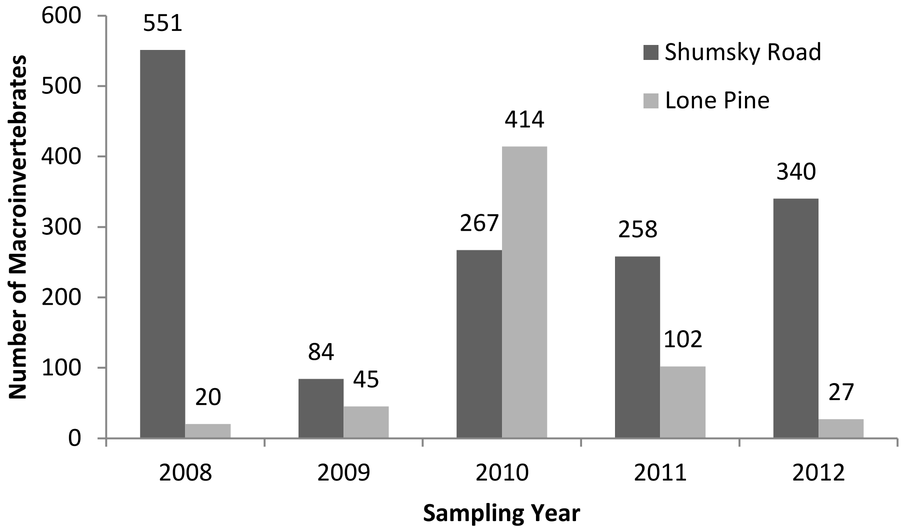
Figure 3. Comparison of macroinvertebrate communities using Simpson's Index of Diversity (*D*) for Shumsky Road and Lone Pine sites along the Boardman River, Grand Traverse County, Michigan, USA. Macroinvertebrates collected annually in June of 2008-2012.

Figure 4. Comparison of EPT/C ratios for macroinvertebrate communities collected from the Shumsky Road and Lone Pine sites along the Boardman River, Grand Traverse County, Michigan, USA. Macroinvertebrates were collected annually in June of 2008-2012.

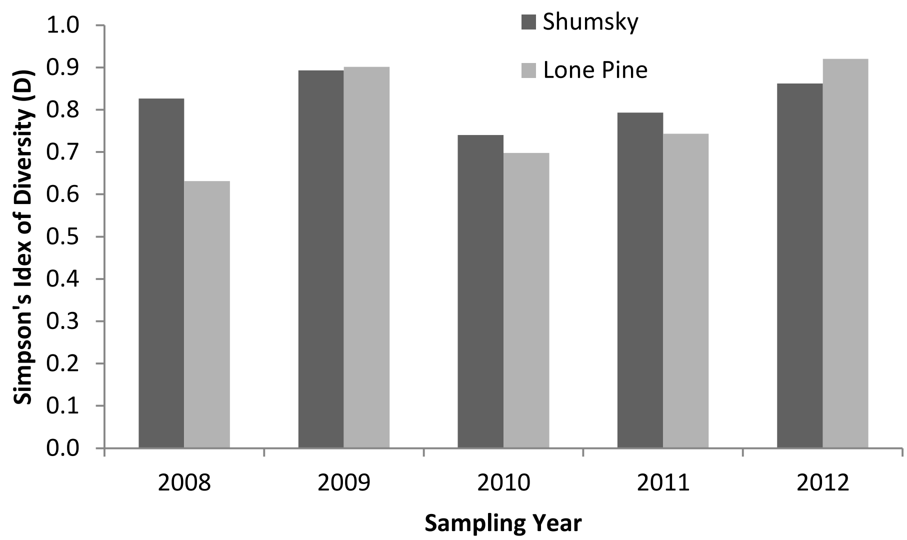
Figure 5. Comparison of Sørensen's Quotient of Similarity (*QS*) for macroinvertebrate communities at Shumsky Road and Lone Pine sites along the Boardman River, Grand Traverse County, Michigan, USA. Macroinvertebrates were collected annually in June of 2008-2012.

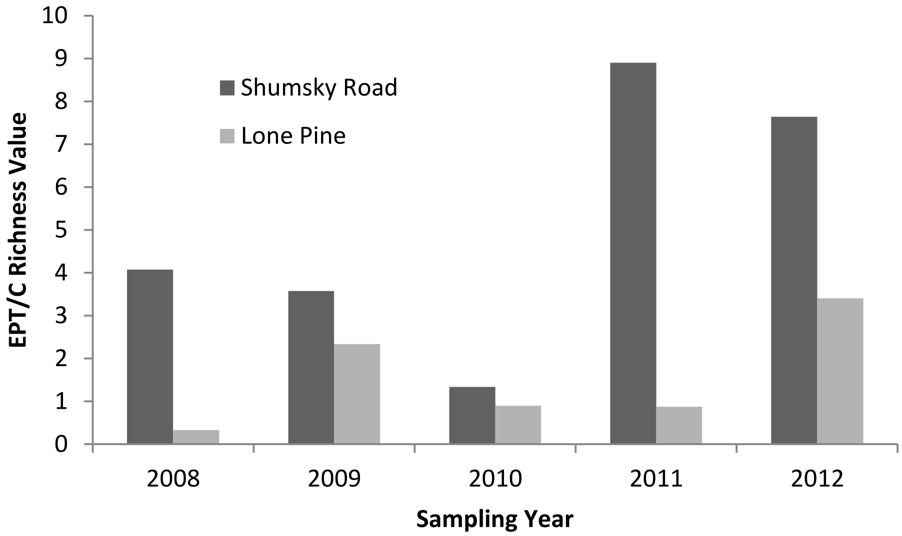
Figure 6. Comparison of sensitive and tolerant individuals for macroinvertebrate communities at Shumsky Road and Lone Pine sites along the Boardman River, Grand Traverse County, Michigan, USA. Macroinvertebrates were collected annually in June of 2008- 2012.

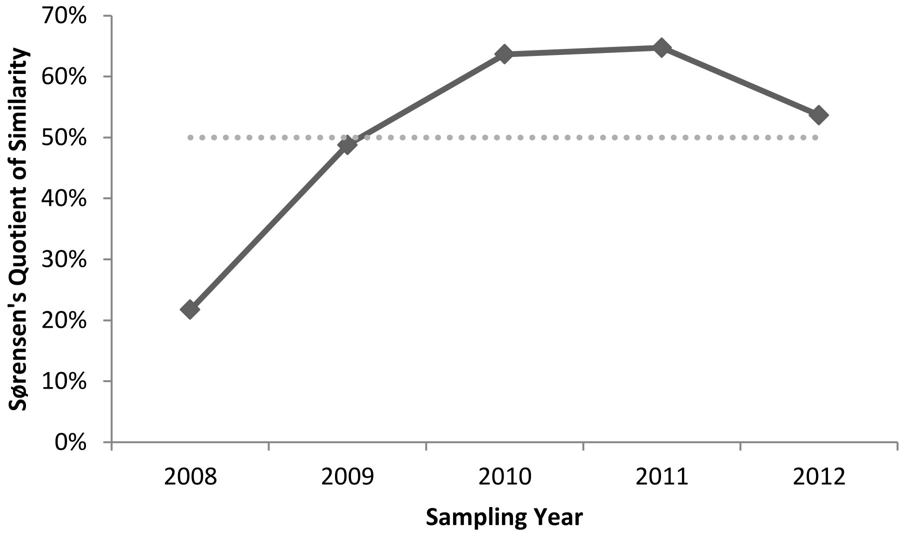

West Arm
East Arm
Traverse City
Boardman Lake
Sabin Pond
Boardman Dam
Keystone Pond
Lone Pine Site
Shumsky Road Site
Brown Bridge Pond
Grand Traverse Bay
Michigan
Boardman River Watershed
0 5 10 20
Kilometers
Grand Traverse County
Kalkaska County
Boardman River
Grand Traverse and Kalkaska Counties
Michigan, USA
0 1 2 3 4 Kilometers
N

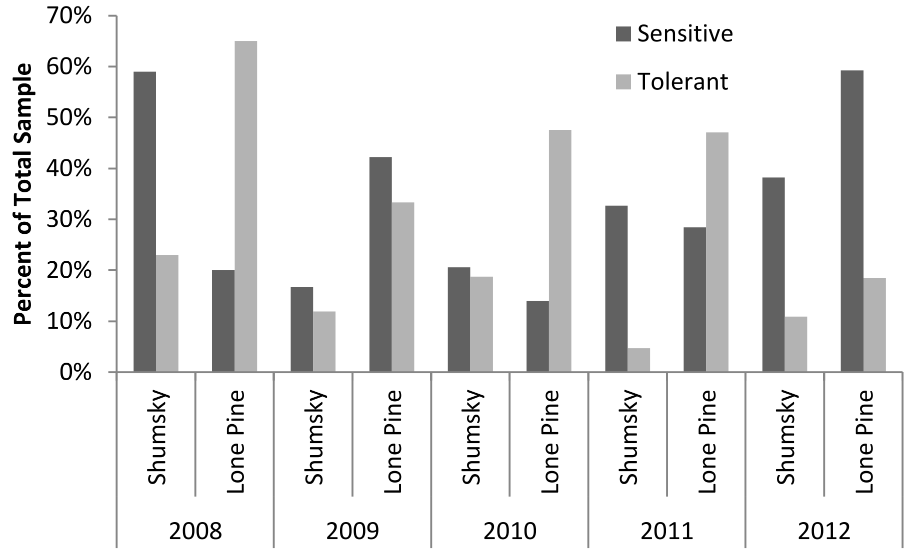


Number of Macroinvertebrates
600
500
400
300
200
100
0
551
20
84
45
267
414
258
102
340
27
2008
2009
2010
2011
2012
Sampling Year
Shumsky Road
Lone Pine


Shumsky
Lone Pine
Simpson's Idex of Diversity (D)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2008
2009
2010
2011
2012
Sampling Year


10
9
8
7
6
5
4
3
2
1
0
EPT/C Richness Value
Shumsky Road
Lone Pine
2008
2009
2010
2011
2012
Sampling Year


70%
60%
50%
40%
30%
20%
10%
0%
Sørensen's Quotient of Similarity
2008
2009
2010
2011
2012
Sampling Year


70%
60%
50%
40%
30%
20%
10%
0%
Percent of Total Sample
Sensitive
Tolerant
Shumsky
Lone Pine
Shumsky
Lone Pine
Shumsky
Lone Pine
Shumsky
Lone Pine
Shumsky
Lone Pine
2008
2009
2010
2011
2012