
Long-term Interactions of a Forest, a Prairie and an Agricultural Field on a Stream Ecosystem: Macroinvertebrate Communities and Water Contamination

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Abstract

Human practices and land use can often have negative and long-term impacts on the interactions and quality of natural ecosystems. The long-term effects of a forest, a prairie and an agricultural field on a neighboring river were studied by comparing the abundance, richness and diversity of each site's macroinvertebrate community to the other two sites. Abiotic characteristics of the stream at each site were recorded to compare physical and chemical variations of the water. The agricultural site had the lowest diversity and was significantly less than the prairie site ($p<0.05$); conversely, the agricultural site had the greatest abundance of macroinvertebrates. Tolerance levels of macroinvertebrates were significantly different between the sites but no significant differences were present in the abiotic factors at the three sites. The decreased diversity coupled with the increased abundance and presence of more tolerance families indicate that the water quality and macroinvertebrate community at the agricultural and forest site were negatively affected by agricultural run-offs. Compared to a previous study of the same sites, this study also demonstrates that the macroinvertebrate community has shifted to more tolerant families at all sites, suggesting that there are long-term consequences of human land use. Improved management policies such as the addition of natural buffer zones along the stream can help maintain the purity and stability of this local aquatic ecosystem.

Introduction

A rising consciousness of ecological problems within the public arena has brought about an increasing awareness and concern for the effects of agriculture on the biotic and abiotic aquatic environment. The cultivation of agricultural lands has changed the natural landscape, which in turn has affected natural interactions within the ecosystem. An emerging trend and a pronounced effect of agriculture is its relationship to surrounding waterways, which due to their proximity to each other have made streams and rivers vulnerable to agricultural run-off (Whiles et al. 2000). The chemical imbalance that results from the additional inflow of chemical nutrients can profoundly alter the diversity, richness and abundance of the macroinvertebrate community in the water. A study conducted by Gammon et al. (1983) provides data that agricultural effects such as nutrient uploading led to an increased abundance of macroinvertebrates in local streams. A second study found that streams in agricultural areas are characterized by low macroinvertebrate species richness and low stability. These changes can significantly modify the food web and bring about severe consequences for the local macroinvertebrate community (Lenat 1984).

Another conflict between agriculture and streams is that fecal matter often accompanies the chemicals that get carried from the agricultural lands to the streams and rivers. According to Fisher et al. (2000), waterways close to livestock farms showed fecal contamination through elevated levels of *E. coli*. This aspect of the contamination process poses a serious health hazard to local human populations and degrades the natural environment for wildlife (Howell, 1995).

The stream studied in this project is Chub Creek, located in Dakota County, Minnesota. It is dominantly bordered by agricultural lands but urbanization of the landscape around the stream may occur as the Twin Cities metropolitan area expands. In the past, it has been regarded as a valuable fishery but evidence suggests that fish and wildlife habitat have declined during the last half century. A recent survey conducted by by Dakota County Soil and Water Conservation District resulted in the addition of Chub Creek to Minnesota's impaired waters list in 2004 (SWCD, 2005). The stream doesn't meet the state's water quality standards due to the high amount of fecal coliform bacteria present in the water and it was deemed unsafe for recreational contact such as wading or swimming. The common sources of fecal coliform bacteria include livestock manure, septic systems, wildlife and feedlots. A further assessment in 2005 suggests that the declining water quality persists.

This study will build on the data found in a previous study in order to accurately monitor the continuous long-term effects of a forest, a prairie and agricultural lands on the aquatic environment and quality of nearby stream. The broad objective will be to observe the long-term effects of different landscapes on the water quality and aquatic community of a local stream. The specific goals of this study will be (1) to observe the relative difference in the abundance, diversity and richness of macroinvertebrates in the stream sites bordering a forest, a prairie and agricultural lands; (2) to assess any further change in the abundance, richness or diversity of macroinvertebrates of the 3 stream sites respective to the same 3 sites from a study done 2 years ago; (3) to detect for the presence of fecal pollution in the stream sites.

Methods and Materials:

This study will be an extension of the study conducted by Rebecca Hunt on Chub Creek in Dakota County, MN (Hunt, 2005). Three different ecological landscapes next to Chub Creek were identified as the sampling sites. The designated forest site was located next to County 23. The second site was located on Highway 3, adjacent to agricultural lands that are made up of cattle pastures and soybean fields. The last site served as the prairie site, found at a junction between Highway 47 and High way 53.

Data Collection

Each of the three sites was sampled on October 12, October 21 and November 4, 2007. The abiotic characteristics of each site, which consisted of water temperature, pH of the stream, dissolved oxygen and conductivity, were measured and recorded prior to macroinvertebrate collection.

At each site, macroinvertebrate samples were collected along approximately 0.5 m of the shoreline. The net contents were analyzed on site and the macroinvertebrates were transported back to the lab to be preserved in 70% ethanol. The organisms were then identified to their correct families as well as their tolerance level by the Bouchard identification manual (Bouchard, 2004). The *E. coli* test was performed using water samples from each stream site per the instructions in the 3M Petrifilm manual (2000).

Statistical analysis

One-way ANOVA tests were performed using the statistical analysis software Stata9 according to instructions in the Field Ecology Manual (Shea, 2007). The ANOVA tests were used to determine significant differences in the abiotic factors among the sample sites as well as to compare the family density of different sites. A contingency table was also constructed in Stata9 to compare tolerance levels between the three sites. The diversity of the macroinvertebrate community was found by calculating the Simpson and Shannon diversity indices (Farris, 1991). Abundance and richness were calculated and graphed in Excel.

Results

Macroinvertebrate communities

Differences in macroinvertebrate diversity, richness and abundance occurred between all three sites. The Shannon and Simpson diversity indices had the lowest values at the agricultural site with 1.215 and 0.549 respectively, which indicate that the agricultural site has the lowest macroinvertebrate diversity (Table 1). The prairie site had the highest values with 2.011 for the Shannon index and 0.812 for the Simpson index. Also from Table 1, diversity at the forest site wasn't significantly different from the agricultural site but both the agricultural site and the forest site were significantly different in diversity to the prairie site ($p<0.05$). Richness was greatest at the prairie site which had 12 families and smallest at the agricultural site which had 7 families (Table 2). The prairie site was found to have the least abundance (32 individuals) while the forest site had more than twice that number of individuals (67 individuals). The two common families found in all three sites were Corixidae and Belostamatidae with mean densities of 22 individuals/meter and 3 individuals/meter, respectively (Table 3). Although no significant differences were found between the different sites for the Corixidae ($p = 0.4167$) and Belostamatidae ($p = 0.8528$), Corixidae was the overwhelming dominant family in all sites (Figure 1).

Tolerance levels were significantly different between the three sites ($p = 0.015$). Further analysis of Table 4 shows that the actual number of high tolerance individuals found at the forest site exceeded the expected amount by almost 4 individuals. Conversely, for moderate and low tolerance individuals at the forest site, there were less individuals than were expected. The agricultural site followed this same trend with actual high tolerance individuals more than expected and low tolerance individuals less than expected. The opposite result was found in the prairie site which had only 19 high tolerance individuals when the expected was around 26; more moderate and low tolerance individuals were collected than was anticipated.

Abiotic conditions

No significant differences were found for temperature, pH, conductivity or dissolved oxygen between the three sites. Fecal contamination was found at the forest and prairie site which both had 1 colony-forming unit (CFU) per mL while no CFU was found from the water of the agricultural site. The *E.coli* colonies present in the forest and prairie sites did not exceed the advisory EPA limit of 2.35 CFU/mL (USEPA, 1998)

Discussion

Impact of agriculture

The agricultural site was found to have the lowest diversity and lowest richness from among the three sites. This result is similar to other studies which have shown that a stream bordered by agricultural lands tend to have poor water quality compared to stream sites close to a natural landscape (Townsend et al, 2005). A common characteristic of agricultural sites is that they contain a lower measure of macroinvertebrate richness in comparison to other sites. This reduction in diversity occurs because species intolerant to water contamination will die off, leaving the tolerant individuals with less competition for habitat and food (Gammon 1983). The shift in the macroinvertebrate community towards less diversity demonstrates how the agricultural site is experiencing negative affects on its water quality and the water habitat.

New effects and long-term consequences

The forest site had the most abundance of individual and it contained more high tolerance individuals than were expected. The high total abundance is a symptom of nutrient uploading but this problem is more commonly associated with agricultural sites (Riley et al, 2003). This data contradicts many studies, including one conducted by Omernik (1981), which showed that trees act as effective buffer zone to block nutrient run-off from reaching the stream. Another deviation from previous studies is that the forest site in this study did not yield the greatest values for macroinvertebrate diversity and richness as is usually associated with forest landscapes (Collier et al, 2000). The data suggests that the forest site is experiencing deterioration in its stream habitat as more high tolerance individuals and less low tolerance individuals are found. The decreased water quality can possibly related to the geographical position of the forest site within the stream, which is downstream from the agricultural site. Although the trees can buffer run-off from the immediate landscape at the forest site, it is likely that chemicals and pathogens have been carried down from the agriculture site. Site location can also explain the high diversity at the prairie site as well as the higher quantity of low tolerance individuals than expected. No only do the tall grasslands serve as efficient buffer zones, the prairie site is the site furthest downstream from the agricultural site and therefore is least affected by the run-off carried within the stream.

The macroinvertebrate data also suggests a trend towards high tolerance individuals and lower richness in all sites compared to data from the previous study (Hunt, 2005). In the 2005 study, the total richness between sites ranged from 14 to 19 families and the range of tolerance levels of dominant families were between moderate to high (4 to 9). In contrast, results from this study has shown that total richness between sites has shrunk down to a range of 7 to 12 families while the tolerance levels of dominant families have increased to high levels (9-10). This trend of decreasing water habitat shows the potential for long-term and far-reaching consequences of human land use on Chub Creek.

Aquatic conservation and future studies

It is important to observe and manage the interaction of human land use on nearby aquatic systems in order to cause minimal negative impact on the natural ecosystem. Conservation efforts should be careful to take into account the potential effects of run-off at the immediate site as well as at locations downstream from the source of pollution. Adding natural buffers at the agricultural site could significantly regenerate the health of the macroinvertebrate community as well as improve overall water quality. In the future, continuous monitoring of Chub Creek over an extended period of time will be crucial to creating efficient policies of regulation and conservation that can benefit both agriculture and natural systems.

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563-576.

Table 1. Simpson and Shannon diversity index values for forest, agricultural and prairie sites of Chub Creek, Dakota County, MN. P-value of forest to agricultural site was not significant. Significant p-values of agricultural to prairie and forest to prairie were 0.02 and 0.05, respectively.

	Forest	Agriculture	Prairie
Shannon's Index	1.454	1.215	2.011
Simpson's Index	0.635	0.549	0.812

Table 2. Richness and abundance values for forest, agricultural and prairie sites of Chub Creek, Dakota County, MN.

	Forest	Agriculture	Prairie
Richness	10	7	12
Abundance	67	39	32

Table 3. Mean density values (individuals/meter) for dominant families of forest, agricultural and prairie sites of Chub Creek, Dakota County, MN.

	Forest	Agriculture	Prairie	Total Mean	P-value
Corixidae	26	26	13	22	0.4167
Belostomatidae	4	3	2	3	0.8528

Table 4. Contingency table values for high, moderate and low tolerance individuals among forest, agricultural and prairie sites of Chub Creek, Dakota County, MN.

		Forest	Agriculture	Prairie
High	Actual	57	34	19
	Expected	53.7	31.1	25.5
Moderate	Actual	2	3	5
	Expected	4.9	2.8	2.3
Low	Actual	8	2	8

	Expected	8.7	5.1	4.2

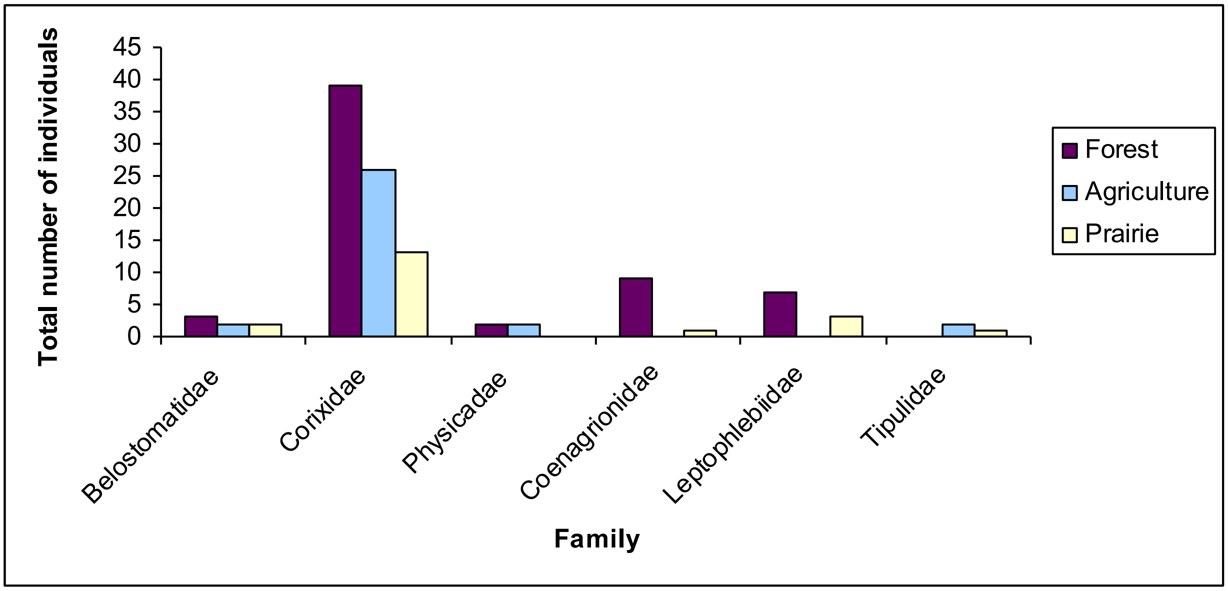

Figure 1. Total abundance for families that appeared in at least 2 of the 3 sample sites (forest, agricultural and prairie sites) at Chub Creek, Dakota County, MN.

Appendix.

A. Raw macroinvertebrate data for all three sites

Agriculture

Latin name	Common name	Tolerance Level	12-Oct	21-Oct	4-Nov	Total
Belostomatidae	Water bug	10 (high)	2		1	3
Coenagrionidae	Damselflies	9 (high)	5		4	9
Corixidae	Water bug	9 (high)	3	32	4	39
Scirtidae	Marsh beetle	7 (high)	3			3
Physicadae	Snail	7 (high)	1		1	2
Planorbidae	Snail	7(high)		1		1
Calopterygidae	Damselflies	5 (moderate)		1		1
Gyrinidae	Beetle	4 (moderate		1		1
Leptophlebiidae	Mayflies	2 (low)			7	7
Corydalidae	Alderfly	0 (low)		1		1

Forest

Latin name	Common name	Tolerance Level	12-Oct	21-Oct	4-Nov	Total
Belostomatidae	Water bug	10 (high)	2			2
Corixidae	Water bug	9 (high)	4	22		26
Libellulidae	Dragonfly	7(high)	1		2	3
Physicadae	Snail	7 (high)		1	1	2
Lymnaeidae	snail	7 (high)			1	1
Dytiscidae	Diving beetle	5 (moderate)	1	1	1	3
Tipulidae	Crane fly	3 (low)	2			2

Prairie

Latin name	Common name	Tolerance Level	12-Oct	21-Oct	4-Nov	Total
Belostomatidae	Water bug	10 (high)	1	1		2
Corixidae	Water bug	9 (high)		3	10	13
Coenagrionidae	Damselflies	9 (high)			1	1
Haliplidae	Water beetles	7 (high)			3	3
Hydropsychidae	Caddisfly	4 (moderate)			1	1
Phryganeidae	Caddisfly	4 (moderate)			1	1
Gammaridae	Scuds	4 (moderate)			2	2
Baetidae	Mayflies	4 (moderate)			1	1
Tipulidae	Crane fly	3 (low)			1	1
Perlodidae	Stoneflies	2 (low)			2	2
Leptophlebiidae	Mayflies	2 (low)			3	3

Lepidostomatidae	Caddisfly	1 (low)			2	2

B. Raw data on abiotic characteristics for all three sites

Date	Site	pH	Conductivity	Temperature	Dissoved O_2
10/12/2007	Forest	8.3	458	10.3	7.81
10/21/2007	Forest	7.6	581	11.4	6.48
11/4/2007	Forest	8	645	6.6	12.75
10/12/2007	Agriculture	7.9	677	10.6	10.7
10/21/2007	Agriculture	8.1	618	11.7	8.61
11/4/2007	Agriculture	8.2	695	7.2	13.06
10/12/2007	Prairie	8	671	10.7	11.61
10/21/2007	Prairie	8	612	11.7	9.12
11/4/2007	Prairie	8.1	690	7.4	14.45