Tillers 2004, **5**, 5-8

Biological assessment of the effects of a hog confinement farm on the North Skunk River in central Iowa

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Abstract

Agriculture dominates the Iowa landscape and is a major polluter of local waterways. An appropriate method of assessing water degradation is the use of macroinvertebrates in biomonitoring. We conducted a comparative study of the aquatic macroinvertebrate communities located above and below a central Iowa hog confinement farm located on the North Skunk River. We identified macroinvertebrates belonging to 17 different families and classified each family according to a system in which macroinvertebrate taxa are listed under one of three pollution tolerance groupings: sensitive, moderately sensitive, and tolerant. Our results indicated poor water quality overall with a marginally non-significant difference between the upstream and downstream sampling sites. No significant difference was found in abundance or richness values of the samples. While little tangible evidence was gathered as to the direct effects of the hog confinement farm, it was apparent that the North Skunk River is highly polluted. The far-reaching effects of this pollution necessitate further study in order to better understand and prevent future pollution.

Introduction

Land use greatly affects the condition of surrounding water and in turn all life depending on it; thus, it is imperative that water quality be closely monitored. The majority of aquatic contamination is a result of agricultural activities (Carpenter et al 1998). In 1997, Iowa's hog industry produced over 27 million hogs (Hanson et al 1997), and livestock confinement farms manufacturing such masses possess a great potential for waste management failure (Anderson and Magleby 1997). A recent article in the Sioux Falls Argus Leader reported that 87 manure-related fish kills have occurred in Iowa since 1997 (Shouse 2004).

The impact of such agricultural activity on the state's water supply can best be determined through water quality assessment. The traditional scientific practice of using physical and chemical measurements to determine water quality only provides an instantaneous assessment of the conditions (Rosenberg and Resh 1996). Biological assessment, however, examines living components of the community, therefore providing an evaluation of the long-term effects (Rosenberg and Resh 1996). Macroinvertebrates vary in their responses to pollution (Chessman 1994), and are therefore good indicators of pollution's existence in water. These organisms are easy to sample due to their small size and limited mobility (Hershey and Lamberti 2001). The biomonitoring technique using macroinvertebrates has been widely employed in such studies as Kondratieff and Simmons (1982), who reported that a secondary sewage treatment plant was polluting a nearby stream.

Despite Iowa's high fish kill rates, very few published reports on water quality studies in Iowa have used biological assessment to examine the effects of pollution (pers. comm. Dr. C. N. Spencer). In 2001, a hog confinement farm was built in Jasper county, of South central Iowa, on the flood plain of the North Skunk River (pers. comm. J. M. Brown). Using macroinvertebrates as a basis for bioassessment, we measured the effect of the hog confinement on water quality through a comparative study of the aquatic macroinvertebrate communities located above and below the farm.

Methods

We sampled from two stream sites, one above and one below a hog confinement farm located roughly 300 m from the North Skunk River of Central Iowa (Figure 1). The sites were approximately 750 meters apart. We began by locating appropriate habitats for collecting invertebrates, which consisted of accumulations of debris such as decaying leaves and other organic matter. Once we identified appropriate sites with comparable rates of flow, depth, and temperature, we collected invertebrate samples. At each site we sampled from three replicates on the afternoon of October 27, 2004. A replicate consisted of 45 seconds of sampling in which we positioned our standard D-net downstream of the accumulation and stirred up the habitat with a stick, allowing all debris to flow into the net.

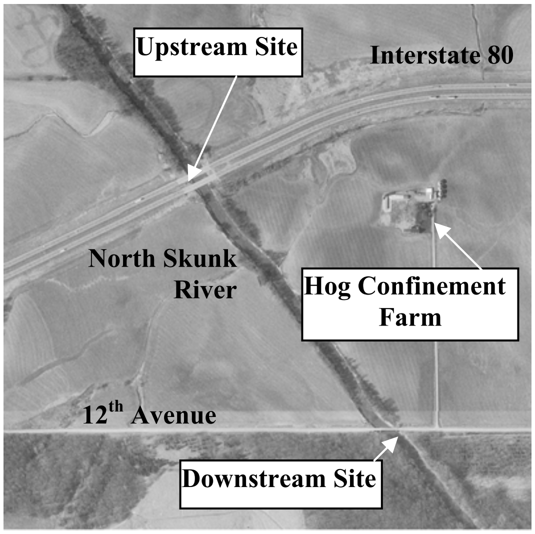

Figure 1: Aerial Photo of study site
(Photo courtesy of the online Iowa Geographic Map Server - Iowa State University Geographic Information Systems Support & Research Facility)

After collection, we washed the contents of the net into a double-layered zip-lock bag and preserved them with 90% ethanol.

Visible macroinvertebrates in each sample were identified to family using *A Guide to Common Freshwater Invertebrates of North America* (Voshell 2002). Water quality was assessed in several different ways: First, we calculated family richness values and family diversity using the Shannon-Weaver diversity index. We then classified each family according to its pollution tolerance groupings: sensitive, moderately sensitive, and tolerant, following a guide provided by S. Kolbe. Next, water quality was assessed using an index calculated by:

WQ value = 1(# of tolerant taxa present) + 2(# of moderately sensitive taxa present) + 3(# of sensitive taxa present)

This was then compared to the following scale: <11 is poor, 11-16 is fair, 17-22 is good, and >22 is excellent, as included in the same guide. Finally, we ran t-tests on all our data to determine the differences in means.

Order	Family
Ephemeroptera	Leptohyphidae
Ephemeroptera	Heptageniidae
Ephemeroptera	Baetidae
Ephemeroptera	Caenidae
Ephemeroptera	(unidentified family)
Ephemeroptera	(unidentified family)
Plecoptera	Perlidae
Plecoptera	Leuctridae
Plecoptera	Chloroperlidae
Anisoptera	Aeshnidae
Trichoptera	Hydrosychidae
Coleoptera	Elmidae
Diptera	Chironomidae
Diptera	Empididae
Diptera	Tipulidae
Diptera	Simuliidae
Diptera	(unidentified family)

Table 1: Orders and families of all macroinvertebrates identified from samples collected upstream and downstream of a hog confinement farm

Results

We collected 17 families from 6 orders (Table 1), which represented all three pollution tolerance groupings. We found no significant difference in the abundance values of the pollution sensitive, moderately sensitive, and pollution tolerant groupings between upstream and downstream sites (Figure 2). The mean family richness values were non-significantly higher (29.3%) upstream vs. downstream (P= 0.115, t= 2.24) (Figure 3). Shannon-Weaver diversity index values were not significantly different between the different sites (Figure 4). Mean values for the water quality index were 36.4% higher in upstream samples as compared to downstream samples, a marginally non-significant difference (P=0.085, t= -2.53) (Figure 5). While these upstream index values were slightly higher, both upstream and downstream sample sites fell within the 'poor' range (<10) on the water quality rating scale.

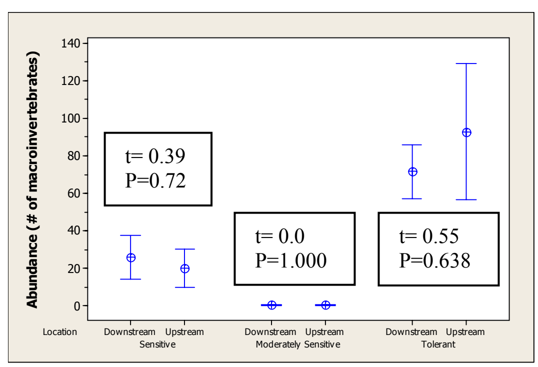

Figure 2: Comparison of the abundance of three pollution tolerance groupings of macroinvertebrates collected upstream and downstream of a hog confinement farm (+/- S.E.)

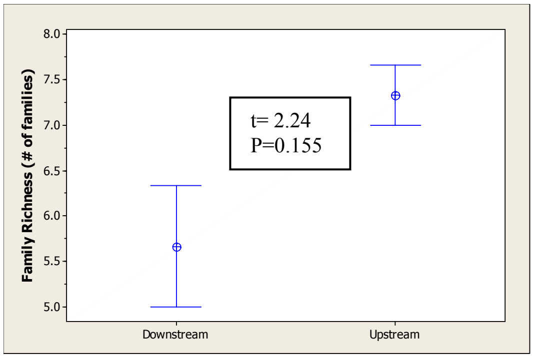

Figure 3: Comparison of family richness values of macroinvertebrates samples collected upstream and downstream of a hog confinement farm (+/- S.E.)

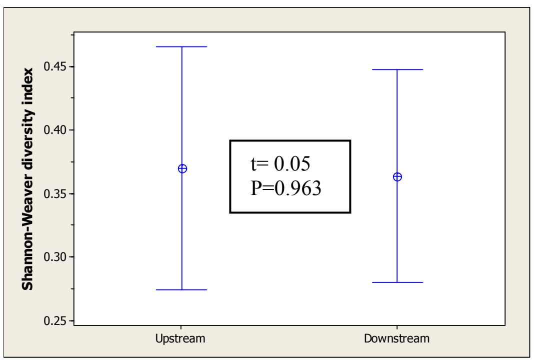

Figure 4: Comparison of diversity index values of macroinvertebrate samples collected upstream and downstream of a hog confinement farm (+/- S.E.)

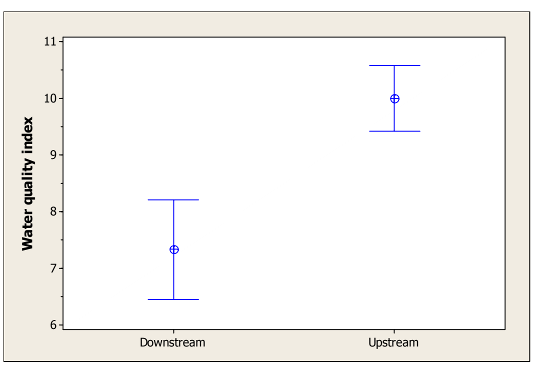

Figure 5: Comparison of water quality index values of samples collected upstream and downstream of a hog confinement farm (+/- S.E)

Discussion

The indication that water quality of the North Skunk River is poor at both sampling sites may mean that organisms in the river are already acclimated to pollution, therefore the effects of any further contamination by the hog confinement farm would be negligible. Agriculture has two main effects on water quality: sedimentation and increased levels of nitrogen. The 1995 agricultural census reported that nitrogen was applied to approximately 97 percent of corn crops in Iowa (Sands and Holden 1996). A 1993 study by Goolsby and Battaglin reported that 15% of nitrogen fertilizer used in the Mississippi River Basin ends up in the Gulf of Mexico (Anderson and Magleby 1997). Therefore, a considerable amount of nitrogen from the surrounding fields may have entered the North Skunk River. Also, sediment deposition resulting from agriculturally-induced erosion has been shown to disturb macroinvertebrate community (Fritz et al 1999). Although the existing pollution may have minimized the effects of the hog confinement farm, it is also possible that since this operation was built so recently, its waste management practices are much more effective than past methods.

Substrate composition could have similarly affected both the types and abundance of macroinvertebrates present. Fine sediments, such as the substrate of the North Skunk River, limit oxygen availability and therefore lower diversity (Hershey and Lamberti 2001). These systems have large numbers of chironomids and certain mayflies (Hershey and Lamberti 2001), as we found in all our samples. These organisms are extremely tolerant of pollution and are therefore poor indicators of changes in water quality (Hershey and Lamberti 2001). Perhaps the effects of the hog confinement farm were insignificant due to the overwhelmingly low diversity brought about by the present substrate.

The geography of the upstream sample site may also have been a confounding variable in our study and could explain why trends in our data were found to be nonsignificant. Road construction increases sedimentation of waterways (Hershey and Lamberti 2001). Since our upstream sample site was located directly below the I-80 overpass, the makeup of the macroinvertebrate community may have been affected. Therefore, our sample may not have been a valid representation of the community pre-exposure to the hog confinement farm.

The water quality index we used may also have been a confounding factor in our study. In their article, Rosenberg and Resh (1996) suggest that biotic indices should be developed according to individual pollutants and specific geographic areas in order to provide a more accurate basis for water quality analysis. We were forced to use an index not specific to the area; thus, our water quality index values may not have been the best indicators of changes in river conditions. There is a clear need for an index developed specifically for Iowa for future studies in this field.

Regardless of whether the hog confinement farm is contributing significantly to aquatic pollution or confounding variables impacted our results, the low level of water quality found in our study raises concerns. It illustrates the necessity of identifying sources of current contamination in order to prevent further pollution. Through further study involving biological assessment using macroinvertebrates, a better understanding of pollution may be reached and utilized in protecting water sources.

Acknowledgments

We would like to thank Professor Jackie Brown, Sue Kolbe, Anna Larimer, and Dr. Craig Spencer for their assistance in the development and research of this study. We would also like to express our appreciation to Kevin Engel, Rebecca Stuhr and Phillip Jones for their guidance in locating primary literature. We also wish to extend our gratitude to Professor Peter Jacobson for the use of his aquatic sampling equipment. Thanks Larissa Mottl and the CERA staff for the use of their and equipment and facilities. We want to acknowledge Judy Hunter of the Writing Lab for her excellent revision and advice on our discussion section. Finally, we wish to express our appreciation to Professor Jackie Brown, Dr. Craig Spencer, Emily Guenther, Lizzie Tegeler, and Will Atlas for their assistance in the editing process.

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